With Professor Bickerton's Compliments

A NEW STORY OF THE STARS

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Portion of a Diagram showing the mode of the Origin of Temporary and Variable Stars, printed in 1879.

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The Triplicity of the new Star in the Chariot and the high velocity of two of its components demonstrated by the Astronomers of Europe and America in the year 1892.

ILLUSTRATED. RE-ISSUE.

1922.

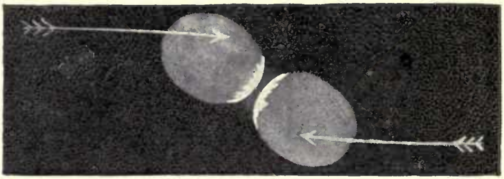

FIG. 1.—PAIR OF STARS DISTORTED AND COMING INTO IMPACT.

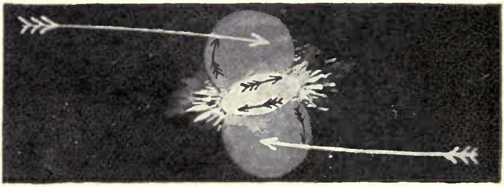

FIG. 2.—PAIR OF STARS IN IMPACT.

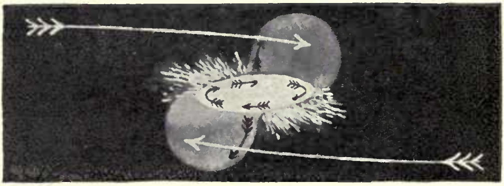

FIG. 3.—STARS PASSING OUT OF IMPACT, AND FORMATION OF THIRD BODY.

FIG. 4.—SHOWING ENTANGLEMENT OF MATTER IN EACH BODY.

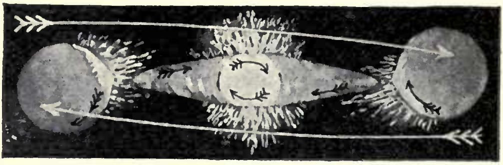

FIG. 5.—TWO VARIABLES AND A TEMPORARY STAR.

Frontispiece.

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A NEW STORY OF THE STARS.

CHAPTER I.

THE EARTH.

A speck of cosmic dust, a mote in space, an insignificant member of a solar system resembling hundreds of millions of systems in our single universe—such is the astronomer's verdict as to the cosmic importance of our world. And we members of the human family, what are we compared in size to a mountain range? And what is the mountain range relative to the earth, the vast earth that it costs us months to circumnavigate? Yet a human being, with his thinking power, is marvellous. And marvellous is any animal, any plant. A leaf is a laboratory built up of wonders, of cells whose complexity is only now beginning to be unfolded to us—by Weismann and others. Then every part of every cell is made up of myriads of molecules, each molecule a regiment of atoms. The spectroscope reveals to us the complexities of atoms. As we examine its lovely chromatic ribbon we are reading atomic songs; the notes are too refined for the ear, the vibrations too small, so we use the eye, and it is the music of colour we perceive. But our very eyesight is too gross for much of this

music, and fluorescence shows us the effect of atomic vibrations in causing fresh atoms to sing. In addition to this vibratory motion, every atom is a storehouse of force; though atoms are so minute that, were an orange magnified to the size of the earth, its atoms would range from shot to shell in dimensions. There are millions upon millions in a drop of water.

Of these singing atoms the earth is built. Mostly, the atoms are locked together in attractive affinities that exist for ages. Sometimes they are changing partners at the rate of the quickest of Scotch reels a million times multiplied; but, locked or free, they are always vibrating. Not all the ingenuity of man, not all his most refined machinery, can cause a single atom to come to rest. Cailletet and Pictet have produced such cold that the motion of the atoms has been greatly reduced; but with all their care the irrepressible atom still moves. In a gas or vapour the particles are free, and fly about, knocking one another and the sides of the vessel containing them, forcing the piston of the giant engines to do the work of thousands of horses, rending rocks in the dynamite explosions, and sending the molten lava of the volcano high into the air. Then we reduce the motion (cool and condense the vapour, we say), and the molecules cling together by their mutual attraction; but they roll freely over one another and slip so easily that a liquid finds its level. Yet even in the liquid there is still a great unrest. Drop a particle of soluble crimson into a tall jar of liquid, leave it a few days, and the restless atoms carry the colour, particle by particle, up the jar till the whole is tinted. Again, reduce the speed of the molecules by

further cooling, and another attraction sets in: the molecules clasp hands, and are locked into a solid. Definite parts of one molecule attract definite parts of others, and lovely forms are produced—the exquisite stellate snowflake, the feathered fern-like hoar frost on the window pane, the marvellous structure which salicine displays under the polarising microscope. Even so common a thing as washing soda is full of beauty; hours may be pleasantly spent in watching the infinite variety of colour and form that the molecules of soda crystals take when forming on a microscopic slide.

On the earth we have the molecules in all three states—tight locked in the granite rock and the steel girder bridge, sliding freely over each other in the water of the great oceans, and free to move in the atmosphere. T'were impossible to imagine the vast number of atoms that make up our globe, yet astronomically, the earth is a particle of cosmic dust, moving forward in space at about twenty miles a second, gaining speed when near the sun, losing it as the distance increases. It moves in a giant ellipse, of which the sun occupies one of the foci. Were gravitation annihilated, or were the attraction of the sun to cease, the earth would move straight forward in space; the solar heat getting less and less until a persistent Arctic temperature would be reached, and life as we now know it would be impossible. But the earth is always falling towards the sun, and this fall and its own onward motion make it move in an ellipse; sometimes hurrying towards the sun, then getting up such a speed by its fall that it is carried by its motion away from the sun again, just

as a comet falls towards the sun, but its tremendous velocity hurries it past without permitting it to fall into the sun. Here is a fertile principle that we shall often have to refer to. Two cosmic bodies attract one another; they come so near as to actually graze, but coalescence does not ensue. They have such "a way on" that they fly from each other almost with the speed of their approach. But what of the graze? Ah! that is the prolific question, the answer to which seems to unriddle the mystery of cosmic evolution! But I anticipate. It is of the flying earth we are speaking; cosmic grazes will occupy us by and by. To make this double action of attraction and flight clear I designed a simple model. I pass a knitting needle through a ball, fix the ends of the needle in a ring, so that the ball will spin, then hang the ring by two cords to the ceiling; and we have a piece of apparatus that I believe will illustrate more great principles than any other I know of. We pull it on one side, and throw it at right angles, and there it moves in an ellipse. It tries to go straight on, but all the time it tries to fall back like a pendulum, and its combination of force and motion makes it move in a circle or an ellipse according to our will, that is, if our skill is commensurate with our will.

Thus we see that, by the attraction of the sun, the earth is prevented escaping into outer space; by its own onward motion it is prevented falling into the sun. The rate of the fall of a moon towards its planet enables us to measure the weight of the planet, provided we know the respective distance; thus, too, we can estimate the weight of the sun by the rate of the fall of

the earth towards the central orb. When Newton thought out his wonderful conception of the laws of gravitation, and tried to compare the rate of a falling moon to that of a falling apple, the size of the earth and the distance of the moon were not rightly determined, and for years the philosopher held his conclusions in suspense. A redetermination of these measurements sent him again to his calculations, to find that the corrections had elevated his wondrous hypothesis into a demonstrated theory—a theory to which every test gives higher certainty and wider range of action. Adams and Leverrier independently calculated the cause of the minute deviations in the motion of Uranus, pointing out where the disturbing element must lie; and through a powerful telescope the planet Neptune disclosed itself, in exact accordance with their statements. Knowing the laws of gravitation, we can weigh the far distant stars, and learn that, in some cases, their stupendous masses dwarf even the giant ruler of our own system. Gravitation enables us to weigh the earth in tons; and, of course, by comparison we may obtain the tonnage of the moon, the planets, some of the stars, and even, remarkable as it appears, the actual weight of dark suns which mortal eyes have never seen. Cavendish's wonderful method—exhibited in the museum at the opening of Canterbury College — illustrates, by the twist of a delicate wire, how much a heavy ball pulls a small weight, compared with the pull of the earth on the same weight. The earth is proved to be a dense massive body ; its mean density more than twice that of its rocky surface, so that its centre is probably six times as dense as its surface, and nearly twenty

times as dense as water. As we dip into the intricacies of the wondrous cosmic agencies, we learn one probable cause for this density. I have shown that in a free gaseous sphere there is a process of selection, by which the light molecules, such as those of hydrogen and helium, tend to become free in space; while the heavy molecules of platinum, gold, mercury, &c., tend to accumulate at the centre of cosmic masses. When I first thought of this action I gave it the name: "Selective Molecular Escape." Dr Johnstone Stoney has recently rediscovered the principle, the notion of which is called by Sir Robert Ball, "most remarkable;" so we may soon have the idea in our text-books, and taught in our public schools.

All who have studied geography know the earth to be a globe, about eight thousand miles in diameter, slightly flattened at the poles by its daily rotation—an "oblate spheroid" in geometric language. Our speck of cosmic dust grows larger on near approach. A cubic foot of water weighs a thousand ounces, the earth is about six times as heavy as water, and it is eight thousand miles through; there are all the data to calculate the number of tons it weighs. The number may be found in any astronomical text-book; but it need not trouble us, our brains are not built the right way to really appreciate such a rank of figures. The earth completes its revolution around the sun in a year, it spins like a top once a day, and there are 365 days or thereabouts in a year. But, oh, the refinements of astronomy! There are solar days and sidereal days, that is, days dependent on the sun and days dependent on the stars; and the sidereal days differ from the solar days, and the solar days are

not exactly one length. We are in a maze of such complex motions that it is better to speak generally and skip details. Otherwise, I might devote this series of articles to the earth, instead of to "A New Story of the Stars"; as it is, the earth and the solar system will yet awhile retard our flight to stellar regions. The earth leans a good deal to one side as it spins, and so, in my suspended ball model, I do not put the needle upright, but lean it at an angle of 23½ degrees. The spinning of the earth causes it to show its back to the sun, and then it is night here—if we consider New Zealand the earth's face, as it seems we certainly must, by the way the rest of the world is following us. Of course, at one time the earth was considered the centre of the universe, and each person's country the centre of the earth, and sometimes a family, sometimes a man, the axis of the country; but these notions are altering. In the geocentric days the sun was beheld as a god driving in a flaming chariot, and Anaxagoras was nearly burnt for doubting his deity. Then the sun was believed to be a fire, perhaps as big as Mount Parnassus, and so ideas developed until Copernicus, with papal consent, drew the daring picture which represented the earth as one of the sun's attendant satellites. The forces of retrogression condemned Galileo to renounce, on his knees, the truths of science. "But, nevertheless, it does move!" whispered the old man. Those same forces had beat in vain against Giordano Bruno; not incarceration, not torture, had evoked recantation from him—therefore was he burned!

CHAPTER II.

THE SOLAR SYSTEM.

The sun—the chief controlling power of the system that bears his name—is a huge ball of fire more than a million times the volume of the earth; a seething, flaming, stormy mass of such magnificent dimensions, that, in point of distance alone, we could not discern a body of the earth's size at the sun's centre, and the orbit of the moon would be a comparatively small circle on his disc. Were the earth the centre of the sun, the circumference of the sublime orb would be twice as distant as the moon is from us now. The cyclones on its face, which we call spots, tell us that our parent globe is rotating in about twenty-eight of our days; and it is thought, such is the tremendous nature of its tumult, that the polar regions whirl round at a different rate from the equatorial. Certainly this is not impossible; nay, it is even probable.

The sun travels in space—taking his family with him—at the rate of about ~~four~~ 12 miles a second, in a direction slightly inclined to his own polar axis. As stellar motions go, the sun's rate is distinctly leisurely, not to say torpid. Some of the stars fly at the rate of hundreds of miles a second; and, when they get up speed for a stellar encounter, the evidence proves that they may strike one another with the inconceivable swiftness of thousands of

miles a second. It is no use to think of astronomic numbers; we can calculate them and talk about them; we can never appreciate them. Still, four miles a second is not to be despised when we look at the Flying Dutchman running along the Great Western Railway, creating a whirlwind of dust, paper, leaves and other *débris* a dozen yards on either side of its mile-a-minute course. The sun's motion, combined with planetary rotation, causes the earth and all the other planets to move in sloping spirals. Of the sun's motion in space, however, we need say little at present. We will consider him as at rest, with the planets revolving round him, and the moons around the planets. There are eight planets; four small dense inner planets, and four outside large planets of small density. A great gap occurs between these two series, and there revolve scores upon scores of minute planets, or planetoids, as they are called. "Bode's law" describes a rough order in the position of the planets, and, according to this order, a planet was missing, for which a society of astronomers was constituted to search. On the first day of the present century Ceres was found in the gap; the following year Pallas; then Juno, then Vesta, and so on and on, till nearly 200 tiny spheres are named. What of these? I hope to discuss them later; but just now will say that, whatever arguments to the contrary, I think them the fragments of a planet which has been shattered, as I also believe Saturn's meteoric rings to be. There are other explanations, but cosmic agencies may so easily blow a planet to pieces: if a body of sufficient dimensions with a velocity of a

hundred miles a second were to plunge into the earth, the fragments would take erratic courses in space, and would then form themselves into a new belt of planetoids. However our planetoids have been caused, there they are, dividing the planets into two well-marked groups: the inner group, Mercury, Venus, Earth, Mars; the outer, Jupiter, Saturn, Uranus, Neptune.

The nearer to the sun, the more quickly the planet travels; thus, Mercury travels at about ten times the speed of Neptune, and gets around its circuit in eighty-seven days, while Neptune takes more than sixty thousand days to complete one revolution. All the planets revolve, roughly speaking, in one plane. All but one rotate in the same direction that they revolve. Laplace's nebular hypothesis of the origin of systems has, doubtless, a good deal of truth in it; but his theory that planets and moons originate by the release of rings belongs, I am afraid, to the limbo of the past. Anyway, the planets' axes being at all angles, and Uranus even believed to go the wrong way, makes the theory difficult to digest.

Of the origin of planets, I shall hope to show later on, something, perhaps far less fanciful, certainly far less fascinating than the ring theory. One regrets to shatter old notions; but truth is keen and often painful; yet, like a surgeon's knife cutting away gangrene, it is followed by health. Few can use the light of truth without being more or less scorched by its flame.

Thus we see that the planets are a series of eight globes divided by the belt of planetoids into two groups of four each. All the planets and planetoids speed on in their course around the sun in one direc-

tion; and all, save the planetoids, roughly speaking, in the same plane. All but one are spinning in the same direction that they revolve in, but the axes of their rotation are inclined very differently. Jupiter, the giant planet, is nearly upright, whilst Uranus has its axis almost in the plane of its orbit. Venus is inclined more than an angle of 45deg; whilst the earth, Mars, and Saturn are all tipped a little more than the fourth of a quadrant. The tipping of the axes produces the seasons; so it is always spring-time in Jupiter; whilst poor Uranus presents one pole to the sun for about a quarter of a century; then spring comes, and for twenty-five years he is side on to the sun, gradually presenting the other pole. So Uranus has a day and night corresponding with his winter and summer, lasting roughly twenty-five of our years; when autumn and spring come there are days and nights corresponding to his rotation. If there are inhabitants they must lead a strange kind of life. I suppose they travel with the summer and chase it round their globe. Venus has tremendous seasons, twice as acute as those of the earth; and there the sun is about twice as hot. The seasons of Mars and Saturn are similar to the earth's, only Saturn's year is about twelve times as long as ours.

The days of Mercury, Venus and Mars are about the same length as the earth's; whilst Jupiter and Saturn have days less than half as long.

Most of the planets have attendant satellites; generally, these revolve roughly in the same plane as the equators of the planets to which they belong, our moon being about five degrees out; so that the apparent path of the moon in the heavens

does not correspond with that of the sun. As far as the moon is concerned, what is called the harvest moon is the only characteristic of seasons. The moon rotates once a month; and so always keeps the same face to us. As the sun sometimes shines on the other side of the moon the face we know is then in the dark; and when by accident the moon gets fairly in front of the sun we have an eclipse. But as the disc of the moon, owing to altered distances, appears sometimes smaller and sometimes larger than the sun, we get different kinds of eclipses, annular when the moon is not large enough to cover the sun, total when it is. The eclipse of the moon is due to its getting into the earth's shadow. That the moon always presents the same face to us is probably due to an interesting tidal action. Both the sun and moon cause tides on the earth; but, owing to the nearness of the moon, the action is chiefly lunar. When both act together we get the spring tides. The so-called tidal waves are generally volcanic in origin, due to the earth shivering when internal contraction causes the surface to crush. The tides bulge up on both sides of the earth; away from, and towards the moon. She attracts the near ocean more than the earth; she attracts the body of the earth more than the distant ocean. Thus one side bulges up because it is pulled away from the earth; the other side because it is left behind. But if the moon produces such tides on the broken-up ocean, what must it have done when all the earth was fluid? And what must have been the tides in the moon produced by the fifty times as big and twice as dense earth? The earth is nearly a hundred times as heavy as the moon. I expect the

moon does not possess the earth's proportion of gold and platinum at her centre to keep down her buoyancy. However that may be, the tidal action of the earth on the moon when she was liquid must have been enormous. Tides act as a brake and stop rotation; so if we were to put up water-power and use the estuary we should, as it were, utilise the brake that is stopping the earth. Just as sparks fly out of a railway brake because of the change of motion into heat, so the tides warm the water of the ocean. When we intercept the water we may do work by tidal engines, but there is just the same heat finally produced; so all energy seems to run to heat. This is Lord Kelvin's great generalisation, called the dissipation of energy, which, baldly stated, implies that all matter tends to gravitate to one huge lifeless orb and all energy to dissipate to useless heat.

This conclusion of universal death is intensely repugnant to mankind, and has only been accepted after the most persistent search for a means of escape. Hitherto the search has failed; but I hope to show later on that there are most complex and wonderful interacting agencies which go to prove that, taken as a whole, the cosmos is immortal, and the present but a phase of an eternal rhythm. The tremendous earth tides on the fluid moon acted as a brake on the moon's rotation, and so slowed it down until it presented the same face to the earth. But the younger Darwin has demonstrated that not all this energy went to warm the moon. It was converted into potential energy, and sent the moon to a distance, much further from the earth than it formerly had; and probably the nearer planets have had their

distances from the sun increased in the same way. Of course, when the moon was nearer, the tides were higher.

The moon probably belongs to the sun's true family, as do also another set of far smaller bodies—the meteors that constitute the zodiacal light; whilst the periodic comets and meteoric swarms are adopted children, and the errant comets only passing visitors. The zodiacal light is a huge, bun-shaped, luminous mass, often to be seen after the sun has set, sticking up aslant to the horizon in the plane of the ecliptic. I hope to show that, in one state of the solar system, much of its matter consisted of countless myriads of millions of meteoric masses—coalesced molecules, and cosmic dust generally, all whirling in an atmosphere of rare gas. The zodiacal light may possibly be the remains of this *débris*, not yet absorbed by the sun. It probably accounts for the wondrous light, called the corona of the sun, that is seen during a total eclipse. Those bodies that revolve near the sun move with a velocity of over three hundred miles a second, and if a large one met a dense errant body visiting the sun—from an opposite direction—there would be a collision that would easily account for the brilliant solar flashes, and for that particular one that produced recently such a violent magnetic storm, upsetting our telegraphic instruments and culminating in the most beautiful series of auroras at both poles of the earth.

The sun, planets, moon, and zodiacal light are possibly legitimate relations united into a group after the great collision that wedded the two pre-solar masses from which I imagine the system originated. The members of the family adopted since

do not amount to much. There are a few comets and meteoric swarms that we know of; there may be an infinity of meteoric swarms we don't know of; because only those that intersect the earth's orbit, and sometimes plunge into our atmosphere, are visible to us. There may be myriads of other bodies than comets revolving in our system that we do not see. We see comets because of their physical condition. Comets are probably swarms of particles orbitally connected. When these get near the sun a tremendous tidal action sets up that makes the constituent bodies rub one another and collide in all kinds of manners, producing luminosity by impact and electricity by friction; and so our dust visitor lights up and becomes visible. Were he solid we should not see him. In a research made in England I showed that under certain conditions positively charged hot gas tends to escape from an electrified body, leaving it negative. Perhaps, the sun is in this condition, and hence, when the comet charges itself with electricity, the sun attracts positive and repels negative, and the inductive action of this electricity produces the luminous tail that always points away from the sun. Anyway, the tail does not belong to the comet, any more than the objects illuminated by a search-light belong to the light. There is another action of the sun on a comet: it may pull part away from the effective attraction of the remainder, or may pull it to pieces altogether and convert the dusty body into a dust swarm. The comets must be much heavier than usually thought, or they would always be pulled to pieces when near the sun. The November and August meteors are such

dust swarms, that plunge into the earth's atmosphere and give us the wondrous meteoric displays, all seeming to spring from a point—that is, the line of flight. Sometimes we get into the thick of the stream, and then it is surpassingly beautiful; sometimes we meet only a thin cloud of dust, and then we are somewhat disappointed. But astronomers are gradually getting to know where the dense and rare parts are, and can foretell the event. Of the errant comets little can be said; they are nomadic creatures that visit us, and then fly on into distant space, and for hundreds of thousands of years wend their solitary course until they get into another system. Perhaps, when they find the conditions consonant, they may stay, as our adopted comets stay with us; but comets are very irregular in their habits. Their orbits are wildly eccentric, and their planes hardly conform at all to those of the staid planets. They are real daughters of Heth, wondrously attractive and beautiful at times; but we must part even from them, and, having torn ourselves away, take our flight to stellar regions.

CHAPTER III.

THE STELLAR REGIONS.

**Twinkle, twinkle, little star;
How I wonder what you are!**

Thus runs the old rhyme; and, now that we know so much about the stars, our wonder is still greater, although of another kind. We are amazed at the marvels unfolded to us, at the majesty of the creation and the vastness of the scale upon which it is built. The distances of the stars from us, and from each other, are so enormous, that double stars, which, in a powerful telescope will not divide, examined by the spectroscope are found to be revolving around each other in orbits it would take an express train hundreds of years to traverse. How are these distances measured? By a property of the triangle. Upon the same base, and upon the same side of it, there cannot be two triangles that have their sides which are terminated in one extremity of the base equal to one another, and likewise those which are terminated in the other extremity, equal to one another (Euclid, Book I, proposition vii.)—by which the old Greek means if the sides of a triangle are stiff, you cannot alter its shape. You may carefully make a five-barred gate, nail it strongly; but unless you put a diagonal, the gate will sag. The diagonal ties it into two triangles and then it is rigid. So if we have a base line and a distant

point, the distance to the point from each end of the line, and the angles the point subtends to the line are rigidly fixed. Therefore if we know the length of the lines, we can calculate the angles; and if we know the base, and the angles at its ends, we can calculate the distances. The art of doing this is called trigonometry. The trig stations on the Port Hills are points measured in this way by the theodolite—a telescope on a divided circle. Our college equatorial has the same graduated circle, only larger. Equatorials generally have clockwork mechanisms by which they overcome the rotation of the earth, and move backwards and thus point to the same place in the sky. So accurate is this triangle method of measurement that surveys of hundreds of miles are often but a few feet out.

This is how we measure astronomical distances. A base line on the earth is measured, and a point on the moon's surface chosen; and by the length of the line and the angles at its ends, we can measure the moon's distance. By a somewhat more complex process, taking advantage of the passage of Venus across the sun's disc, we can measure the distance of the sun. But we can check our solar measurement. By experiment we can determine the speed of light: it is over 180,000 miles a second, about ten million times as fast as the quickest express train. By the eclipses of the satellites of the planets we can tell how long light takes to travel from the sun; and thus, by two methods, we get the distance of the sun and the size of the earth's orbit. Of course, the orbit is an ellipse and does not measure the same in all parts. To measure the distance of the

stars we use the earth's orbit as a base line. It is over a hundred and eighty millions of miles in diameter. At intervals of six months, the angle a star makes is measured. The angle is so small that only the most accurate workers and the most gigantic and exquisite instruments are able to detect any difference. But year by year the observations are compared and defects are eliminated, until at length there is considerable certainty as to the distance. And what a revelation it is! It would take the swiftest express train forty millions of years to get to the nearest star. It takes light over four years to travel from it to the earth. This star, Alpha Centauri, is not seen in England. It is the brightest star of the constellation Centaur.

The stars move, and by their distances we can calculate their speed across the line of vision. But, wonderful to relate, without knowing their distances, we can calculate their speed in the line of vision by means of the spectroscope; and the revelations of the spectroscope only confirm the calculations from telescopic observation. If light takes over four years to come from the nearest star, how long does it take from the most distant? Probably thousands of years. As far as I can judge by the data available, the huge dead suns that in 1892 gave us the marvellous Nova Aurigae probably crashed through each other before the battle of Crecy was fought. Then, for hundreds on hundreds of years, the message of the vibrating atoms carved the ether into ripples that told system after system of the stupendous phenomenon which had occurred; then the vibrations reached the earth just in time to be deciphered by astronomers. Had the message come a few years before, it would

have fallen on uninstructed senses, and would have been quite lost to humankind. Unfortunately, although the senses were trained the intellect was not. The proverb, "The eye is blind when the mind does not see," is intensely true of telescopic observation. Had the observers been aware that a new temporary star must consist of three bodies, as I had shown by reasoning, and illustrated by diagrams nearly a score of years ago, the whole life history of such stars would probably be known to us now. Vogel's observing power is wonderful; whilst other observers suspected the existence of the broad middle band which told of the brilliant grazed-off mass, he clearly identified it, and even measured its velocity in space. In the cause of science, it is to be hoped that the intellectual inhospitality which has closed its doors to the theory of partial impact may have passed before any other brilliant temporary star adds lustre to our heavens.

Such, then, are the distances of the stars; what of their size? A million, ten millions, hundreds of millions of times the volume of the earth are common dimensions. Thousands and tens of thousands, perchance hundreds of thousands of millions of times the volume of the earth some of them seem to be. I estimated that those two dark clashing orbs were four thousand and eight thousand times the mass of the sun. It is no use to worry about these sizes; we simply do not understand them. We can calculate them perfectly, as we can calculate the heat produced by impact; but what is the use to say it is a hundred thousand times as hot as a blast furnace? Our intelligence does not reach such intensities any more than it does such volumes,

such speeds or such numbers. Think of it! Over a hundred million suns in our single universe, besides nebulæ of all kinds, star clusters, meteoric swarms, &c., We know they all exist, but to conceive their greatness is beyond us altogether.

The stars then are suns, in absolutely inconceivable numbers, spread chiefly in a giant ring, called the Milky Way, or Galaxy. In this same ring are all kinds of marvels besides the stars. There are gigantic cloud-like irregular masses, such as the great nebulæ of Orion; also, stupendous disc-looking masses, called planetary nebulæ, which, Herschel says, are shells of gas so gigantic that our solar system might be placed edge on seven times within some of them. Then there are temporary stars — stars that flash suddenly into sight, sometimes expanding till they are the brightest bodies in the entire heavens—probably globes of fire as large as the orbit of the earth, they go on expanding into space, and finally disappear. Then variable stars, that sometimes seem to go out for months and then reappear or exhibit periodic differences of luminosity. Mira, the Wonderful, seems to me to be a giant dark sun that has had a portion struck off, and thus exposed its molten interior. Doubtless every cosmic body of gigantic dimensions is hot-centred. The tremendous impact no doubt set Mira spinning; and as it goes on rotating it turns alternately its brilliant and dark sides to us. Then we have the so-called twin suns, of which there are many thousands; but this is not a good name. They are probably not true twins but married pairs. It is a case of marriage by capture; the two have come together, and the most brilliant marriage ceremony

imaginable ensued, such a display of fireworks as the minds of Brock or Paine have never conceived, and such death and devastation at the festivities that the thousands crushed to death at the coronation of the Czar were nothing to it. Some sixteen years ago I described in detail the whole ceremony by which suns became wedded into inseparable pairs, and I hope shortly to give my readers some of the salient details when we come to that part of the subject.

But we have also triple and quadruple stars to think about; in fact, groups of every kind, up to immense clusters of orbitally associated suns, many of them so exquisitely coloured that in a good telescope they look like a collection of variously-tinted gems. Still there are more marvels in the Milky Way—dead suns, the existence of some of which has been demonstrated. Many years ago I thought there must be dead suns. In my earlier papers I suggested it might be possible to detect them by their eclipsing others, and in this way dead suns have been found. Of Algol, the Demon, I suggested that it was a double star, consisting of a dead and a lucid sun, and that it was an occasional partial eclipse of the lucid sun by the dead one that gave Algol its demonic qualities. Now, the spectroscope has measured and weighed that dead sun, has told its velocity and the size of its orbit, and pronounces it almost exactly the size of our own sun. Sir Robert Ball lately expressed the opinion that there may be more dead than luminous suns; I have for years thought this. In our slight glance at the denizens of the Milky Way, what a vast series of gems we behold—

> Studding so thick
> The great galactic ring
> Which forms the crown of God!

Before we can realise the majesty of stellar space we have to make acquaintance with the wondrous aggregation of nebulæ at the poles of the Galaxy, and the two Magellanic Clouds; then we may proceed to the mode of stellar evolution.

Let us suppose this Milky Way, this gigantic irregular ring of stars, nebulæ, &c., to be the rim of a wheel — a very rough kind of rim, and plenty of it, as on the carriage wheels of the old Merovingian kings—a rim very battered and broken—perhaps in irregular semi-spirals like the balance of a chronometer. Or, better still, imagine it to be a sort of huge double-gerbed Catherine wheel in full display. Our solar system possibly lies somewhere towards the centre of the wheel, while, if we continue the wheel-axis in both directions, we come to two stupendous aggregations of gaseous bodies, each cap consisting of thousands on thousands of nebulæ of definite and sometimes exquisitely beautiful form. Taking a celestial globe, conventionally, of course, the solar system occupies the centre; encircling the globe in a broad stream runs the Milky Way; on either side of this stream of stars are comparatively bare belts; then, as we travel towards the poles of the Milky Way, instead of stars, star-clusters, &c., we come upon nebulæ. Thicker and thicker swarm the nebulæ as we travel onward; most of them roughly spherical in form, altogether unlike the nebulæ to be found in the Milky Way. But spread amongst them are a number of nebulæ of very wonderful shape—double, triple and quadruple nebulæ; nebulæ just coming into impact; nebulæ in impact; nebulæ passing out of impact with a long spindle between them; every

variety of form resulting from the impact of nebulæ. There are spindles, spindles with incipient spiral at the centre like that of the Lion; fully developed double spirals, double spirals with associated nebulæ, dumb-bell and annular nebulæ, and other forms that, if fully stated, would make this article look like an auctioneer's catalogue.

When I first commenced the study of impact, I thought chiefly of impacting suns—dark or luminous—and of the results of such impacts: temporary, variable, and double stars; planetary nebulæ, star clusters, &c., &c. Presently I began to think of the mechanism of such impacts; I treated the subject kinematically, as scientists would say. Then grew up ideas of lovely forms—spindles, spirals, rings and so on. Everything went as merrily as wedding bells until I thought of the awful outrush of expanding gas that must result from the impact of suns. Oh, the horror of it! All my lovely shapes blown to the four winds! I don't often remember unpleasant things, but writing this recalls that *mauvais quart d'heure*. Then, again, I thought: "But the forms are there, and the mechanism is there to produce the forms. What does it mean?" All at once the impact of nebulæ occurred to me. The kinematics would be the same, but the outrush nothing to speak of in comparison. I knew where the globular nebulæ were spread in the heavens; everything of interest I had worked out yet had been in the Milky Way, however, and I thought these beautiful nebulæ were there also. Had I made a wrong assumption? I tried to borrow a celestial globe, but failed; then, throwing economy to the winds, I bought one, took

the bearing of these celestial flowers, and plotted them. My surmise was right; they were not in the Milky Way, but amongst the globular nebulæ at the poles of the Milky Way. Hence was I happy.

In all probability, then, impacting stars cannot produce these lovely forms, but impacting nebulæ can; and where the nebulæ are thick—giving us the probability of impact of nebulæ—there we find these forms; and in the Milky Way, where the stars are thick, we find the wonders that result from the impact of stars.

The stars in the Milky Way are not without order. We have what Proctor calls star-drift, streams and sprays of stars. I well remember, one clear winter night, chatting on impact with my friend Mr Hay, now of Timaru. We were looking up into the heavens, and I noticed these wonderful sprays. "Why," I said, "Hay, the very universe looks like a case of impact; these streams of stars seem to be the result of a whirl!" Stream after stream we pointed out to one another. I had very imperfect ideas of the universe then; Herschell's old cloven-disc theory was in my mind, and this notion did not fit that at all. I went to "Newcomen's Astronomy," and soon saw I must reconstruct my ideas. Then Proctor's wonderful book, "The Universe," fell into my hands. As I studied it, I saw more and more clearly the marvellous coincidence between the universe as Proctor's great observing power had pictured it, and the result that would be produced by the grazing but coalescent impact of two previously existing universes. It was clear that a rough ring of double spiral character, with sprays and streams of stars, must ensue. It was

clear that such an impact must cover the poles with gaseous matter that in time, by the passage of bodies through it, must become nebulæ and nebulous stars. All irregularities in gravitating groups tend to increase themselves; thus, out of diffused gas grows up cosmic dust; from cosmic dust come star clusters, or solar systems, according to circumstance. But this is anticipating. At present we are trying to know what the cosmos—of which our earth is a part—is like. The mode of its evolution will concern us immediately.

I have tried to give an idea of our universe, very sketchy and imperfect, but the best I can accomplish in the space. But there are wonders in the heavens that seem not to belong to our universe at all; stars that appear to be visitants from other universes, perchance also other universes actually apparent to us, though I suppose the dust of space cuts from our sight most of the universes that probably make up the mighty cosmos as a whole. The two Magellanic clouds probably are independent universes. Mr Russell's remarkable photographs show gigantic spiral structures, with stars, star clusters and every variety of denizen that people our own universe. Is it possible that these are two universes on the way to form, by mutual coalescence, a universe of a higher order? Later on I hope to show how universes form: universes of the first order, then, by coalescence, universes like our own, of more complex structure and higher order, are formed, to partially dissipate and help to form universes of a lower order again. Thus we have birth and death; construction and dissipation of worlds, systems and universes. Everywhere rhythm and order; everywhere majesty and law.

Of marvel and beauty there is no end, whether it be of the stupendously great or of the infinitesimally minute. We dissect a flower, marvelling at its loveliness. Through a lens we see the structure of its parts, its spirals, its delicate reticulations. With a compound microscope we look into the complexity of its cells. Chemically we pull the cells to pieces and get molecules, we analyse the molecules and sort the constituent atoms. Then we apply the spectroscope, and the atoms reveal themselves in song, and tell us of structures so marvellous that our hearts beat with delight in such adaptation of means to ends, and in recognition of the object of creation.

> Joy is God's index of a rightful act,
> Pain is the signal telling man he errs,
> Dire misery points out deep social wrong.

Was Beethoven at fault when he gave us his weird discords? Does not the succeeding harmony ring out the more concordantly? Shall we blame the Creator for the present dissonant conditions of life? Nay, let us learn the lesson and help to bring about the consonance that is so attainable would we but learn the lesson. But all in good time; were it well we had learned it before. To educate to the careful uses of wondrous fire the burn must be keen and long. To me, the richness of human life rendered possible by the applications of science is so marvellous that I seem to hear the first chords of that sublime harmony which is, I believe, to be the immediate future of the race. It may be that still further wrenching discords have to be heard for the full appreciation of the grand concord in store.

We have, then, glanced at a picture of that piece of the mighty cosmos it is

granted us to know about. It is a peep into the infinite.

The theory of impact furnishes a clue to the mystery of cosmic evolution ; by its aid we can trace the stages in the history of the earth, the sun and the universe, and learn that the present is no other than a phase of the eternal. Quotation may here be permitted from a very succinct statement of cosmic evolution on the basis of impact given by the Bradford *Daily Argus* :—

"Shall we have to recast our notions as to the scheme of the universe? It almost seems so. Hitherto it has been an accepted belief that planets and suns and systems are all hastening to one endless death, and the blackness of everlasting night. But from a transplanted Briton in New Zealand —Professor Bickerton, of Canterbury College, Christchurch—comes a newer and more hopeful faith. He has evolved a theory of 'Constructive Impact' which, whilst it offers a plausible explanation of the astronomical problems presented by variable stars, and the new stars which flare into startling brilliance for a few brief astronomical hours, to subside again into obscurity or disappear entirely, also provides for an endless cycle of birth, maturity and death on the part of stars, akin to that which we see around us in organic life. * * * There are other directions in which Professor Bickerton's theory fits into ascertained phenomena, but we have said sufficient to indicate its ingenuity and plausibility. The matter is certainly one which deserves the close attention of astronomers, and it is interesting to the general public as another illustration of the truth underlying the old proverb, that there is nothing new under

the sun. Even the sun and the stars may not be new for aught we know, but may have gone through endless cycles, beginning with the nebular condition as chaotic masses of heated gas, and passing through all phases until the condition of passive death—as shown by our moon—is reached, to be again revivified, reduced to the nebular condition again by other stars with which they have collided. There is nothing inherently improbable in the theory, and no substantial reason why the same birth, growth and death of planets should not go on for all eternity. But how immeasurably does the apparent length of eternity extend when æons represented by the birth and life and death and re-birth of solar systems are the ticking of its pendulum ?"

CHAPTER IV.

TEMPORARY STARS.

In November, 1572, while Good Queen Bess sat on the throne of England, and the blood stains of St Bartholomew had scarcely yet been wiped from the stones of Paris, Tycho Brahe was intently studying the stars in his quiet Danish home. There he was unspeakably astonished to behold a new star of extraordinary brilliancy in the constellation Cassiopeia. It must have appeared quite suddenly, for, Tycho tells us, he believes it was not visible an hour before he noticed it; and even coach-drivers and country people observed it at the same time. When first seen it was very brilliant; but soon became more brilliant than Sirius, it rivalled Jupiter, it was even brighter than Venus at quadrature, it was so bright it could be seen at noonday. It was fixed in space at true stellar distance, therefore it was the most brilliant body in the entire heavens. Probably it gave off over a hundred thousand times as much light as our sun. Then in a short time it began to diminish in intensity; in a few months it was only a star of the second magnitude; and in seventeen months the Pilgrim, as it was called, had faded completely away.

Fully twenty such sudden appearances of stars are recorded, some within the last few years; but these later ones were not pro-

minent objects—telescopes were needed to observe them properly. Yet so marvellously have photography and the spectroscope added to the power of the telescope, that these points of light have given us stellar information which the brilliant visitants of the past never afforded us.

All observation tells the same story of sudden appearance; temporary increase of brilliancy; rapid and generally complete disappearance, sometimes leaving a planetary nebula. A new star is a giant sun that has been suddenly born; a body of surpassing brilliance and inconceivable size; appearing all at once in the universe, to fade away again in a few months. What explanation is there of such a stupendous event? Suggestions there are, startling in their insignificance: the sudden combustion of hydrogen in a dead sun, the bursting out of a volcano, or the plunging of a planet into a dead sun, the passage of a meteoric train through the atmosphere of a dead sun, the tidal disturbance of two dead suns passing near one another, and so on. Think of a bonfire or a volcano ten thousand times the size of our own sun!! Suppose we even imagine such a mass of heated matter to be produced, how long would it take to cool? Our particle of cosmic dust– the earth—probably took hundreds of thousands of years. Our sun has taken tens of millions, and will probably take more than ten million years longer to cool. Yet a body ten thousand times his brilliancy vanishes in a year.

Let us try another explanation, one so obvious, so clearly corresponding to every fact observed, as to seem an actual *vera causa*; an explanation that, when we understand it, reveals not alone the origin of temporary stars, but the mechanism

producing variable and double stars, and, with altered conditions, makes manifest to us the very mode of cosmic evolution.

We have seen how bewilderingly rich in suns, in star clusters, in giant nebulæ, is the great Galaxy. The suns, whether lucid or burnt-out, all in restless motion, all ploughing their way through space at rates of some tens of thousands of miles an hour; every sun attracting all bodies in its vicinity; suns when near each other getting up a speed of hundreds and even thousands of miles a second; when very close attracting each other so powerfully as to elongate themselves egg-wise with their long axes in mutual approach; perchance partly obstructing each other's path, and then crashing into one another. In less than an hour the collision is over. A slice, may be a million miles through, has been cut from each. The shorn suns are flying from each other, leaving the two gigantic fragments to coalesce into a single body of most marvellous potentialities. But not to entangle thought—to simplify it—is the object of these articles; so we will consider the mass in only one of its aspects.

Heat is a motion of molecules. We strike a piece of lead and the motion sets up an internal shiver. As blow after blow is struck the internal motion grows more and more rapid. We drop on the heated lead a little piece of phosphorus; its molecules take up the motion of the lead, and the cohesion that locks the particles into a solid gives way, and the phosphorus melts and volatilises. There is a great attraction between the particles of oxygen in the air and the particles of the phosphorus; they rush together with such velocity and shake one another so violently as to become

intensely white-hot, and we say the phosphorus burns. The power to do work we call energy. There is energy in gunpowder; we call it potential energy. We ignite the gunpowder and the separated particles of carbon and oxygen fly into each other's embrace, and build up new molecules. So tremendous are the affinities of the atoms that the speed of their encounter turns the solid powder to gas, and originates such vibrations in the ether that a flash of light is produced, the molecular motion hurling forward the massive shot more than 100ft. a second, to play havoc with what ever it encounters. But the speed of suns is not measured in feet per second; it is measured in miles per second. And energy is not proportional to speed; it is as the square of the speed. To make a body move twice as fast we have to expend four times the work; to make it move ten times as fast we have to do a hundred times the work. There is more than twenty-five million times the energy in a body moving a mile a second than in one moving a foot a second.

Let us suppose our two suns that grazed each another to be dark, hot-centred bodies. Let us suppose a tenth be cut from each; the shear will not stop them, their tearing speed is so stupendous. The wounded suns go on; but the parts in each other's way must stop each other. A spinning motion will be present, but almost all that violent onward rush will be converted into motion of the particles, that is, into heat. Of course it is impossible to imagine the temperature produced; but, given the chemical composition and the velocity destroyed, what cannot be imagined can be calculated. The heat

would be millions of degrees, thousands of times, greater than that of an electric furnace. But a remarkable principle complicates the problem. The temperature depends on the chemical composition. Substances like lead, built of heavy molecules, take up but little heat in becoming heated; whilst water, and more especially light substances like hydrogen, take up a great quantity. That is the reason why hot water is used for foot-warmers, &c. At present we will neglect the fact of this difference, but it becomes very interesting later on.

The coalesced mass struck from the two suns is therefore intensely hot; it is of course converted into gas. It is too hot to be stable, and the great mass expands at an incredible speed--generally the giant blazing globe would increase more than a score of millions of miles per day. There is no fancy in any of these statements, they are all plain matters of fact, deductions from the known laws of matter and energy; they assert exactly what would happen were a pair of suns to come into partial impact. Therefore, if two dark suns did graze and cut off a tenth of each, it is absolutely certain a new star would appear in the universe. Calculation demonstrates that such graze occupies about half an hour. Singularly enough, with bodies of equal density, the size does not influence the time, because they get up commensurate speed. In this short time, then, a new sun is born. The tremendous expansion and increase in brilliancy sometimes last for days, then a new action sets in.

Temporary stars disappear, not by cooling, but because they are too hot to hold together. All have read of Jules Verne's Columboid, the wondrous-chambered shot that quitted the earth; and, such is human

daring, I have known some ardent souls that longed to make a similar journey. But not so can we visit the moon; we have neither the explosive nor the material to bear the strain. About a thousand times the energy of an ordinary shot would be needed to get up speed sufficient. A shot hurled with a velocity of seven miles a second would leave the earth and not return. All cosmic bodies have a definite velocity at which shots would leave them, and this is called the critical velocity. The molecules of gas are always in motion, which increases with increasing heat. All the particles of the new star are moving with inconceivable speed—hundreds of miles a second. The velocity to allow of bodies escaping from suns of similar density is higher in proportion to the mass of the suns. So the less the mass of the new star the less the speed required to escape from it. Imagine all the molecules are shots above the escaping velocity; when any come to the surface they travel straight on and leave the mass. Hence, the mass expands in two ways: it expands by the tremendous pressure exercised by the molecules striking one another, and also expands because the molecules are always escaping and flying away. Their speed may be taken as a million miles an hour. After some months nothing remains but an immense hollow shell of gas always expanding, in fact, one of Herschell's planetary nebulæ; only such a nebula as here described is not permanent—it continues to expand, and finally strews space with countless wandering molecules, some of which will in later ages form material for the origination of new universes.

So, whatever may yet be explained, it is

certain that a comparatively small partial impact of dead suns must produce a temporary star that will suddenly blaze forth, increase in brilliancy for a few days, then pass away by dissipation into space.

When we come to spectroscopic evidence there remains no room for doubt; but this consideration will be more appropriate in our study of the two great dead suns flying from one another, each bearing the scars of conflict in lakes of fire hundreds of thousands of miles in diameter.

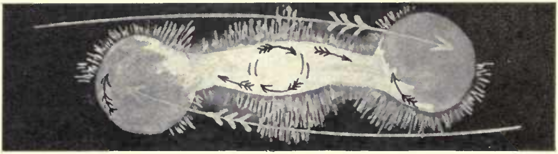

FIG. 7.—DIAGRAM SHOWING FORMATION OF SPINDLE AND ILLUSTRATING THE DIRECTION OF ROTATION IN THE THREE BODIES.

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FIG 8.—DIAGRAM SHOWING THE FORMATION OF THE HEATED MOUNTAINS AND SHOWING THAT IN ROTATING THE TORN SUN CARRIES THE MOUNTAIN IN ADVANCE OF THE VALLEY.

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FIG. 11.—DIAGRAM SHOWING SHADED BLAZE BANDS.
A Spectrogram of Nova Aurigæ.

CHAPTER V.

VARIABLE STARS.

For just about four centuries astronomers have known of an extraordinary star in the constellation of the Whale—Mira, or the Wonderful, the older observers called it. Months elapse without sign of a star; then a faint light appears, that grows stronger and stronger for about three months; for a few weeks it remains brilliant; then during the next three months it fades away again. This process is repeated year after year, the period being computed at 331 days 16hrs. 7min. There are scores, perhaps hundreds, of stars that exhibit periodic fluctuations of intensity, though none are so remarkable as Mira. How are we to explain the peculiarities of these stars? Suppose we were to hang a policeman's lantern on a roasting-jack; it would flash and vanish, giving us an appearance similar to that presented by Mira. But another explanation is possible. Suppose we were to cut a large hole in the side of a tin can, and hang it over a lighted candle and let it spin, we should get the same result. Hence we see that a variable star may be a star with sides unequally heated, which presents these sides alternately to opposite parts of the heavens. Or, there may be something that eclipses the star; we know that the short periodical eclipse of the Demon star is due to the passage of a dead

sun across its disc. But in space there may be dust swarms—huge opaque clouds that revolve around stars and produce eclipses. Of these two ideas the revolving lantern theory best accounts for most of the variable stars. Let us return to our two colliding dead suns. Their partial impact has taken a slice from each and exposed the molten interior. As the two bodies flew from the flaming central mass, their enormous attractive force, and the lack of balance at each edge of the colliding parts, would cause huge tongues of fire to follow each retreating orb. The collision would also cause each of the two colliding suns to spin, and to present alternately a light and a dark face towards the same part of space. Thus easily is the mystery of variable stars explained. Deduction, therefore, from the well-known laws of matter and energy demonstrates that a partial collision of extinct suns produces three bodies: an immense flaming ball of fire, glowing and expanding at an enormous rate, and two cosmic bodies flying from each other at inconceivable velocities, each of these cosmic bodies revolving and unequally heated on their two sides. Presently, by mutual attraction, the velocity of the two bodies becomes so much reduced that the central expanding gaseous body overtakes them and envelopes them, and they become a double variable star within an immense planetary nebula.

Has such a complex phenomenon as this ever been observed? New Zealand is so remote from the centre of scientific activity that it is difficult to get full information, and where no theory exists to guide observers very much is missed; thus the evidence is somewhat conflicting.

Fortunately, there are summaries by collectors of observations, one giving the result of the work of over eighty observers, and their summaries agree. The prismatic light of these celestial visitants is very extraordinary. Instead of the coloured lines that usually represent the notes of the vibrating atoms, the ribbon of light is crossed with broad, indistinct bands, and on either side of the centre of each of these bands is superimposed a line. By the rainbow-tinted ribbon the stars tell us their story. How are we to read this stellar message?

When a beam of white light falls upon a prism it is bent to one side; but white light is made up of waves of many lengths, growing shorter, from red, through all the colours of the spectrum, to violet. Let us then imagine a beam of white light to consist of long waves striding onward and shorter waves running to keep up, so that all travel at the same rate. These waves meet the prism, and their directions are altered; the shorter they are the more they are deflected; so they accompany each other no more, but diverge wider and wider till the bright beam of white light is coloured and fan shaped, and when it falls on a white screen, is a long coloured streak. But the streak from the light of the stars is uneven, in fact, sometimes broken; there is not a regular succession of waves of all lengths, they are largely the characteristic waves corresponding to the notes given out by the atoms. It is by the length of the waves we recognise the atoms producing them. But in the new star spectrum the notes are out of tune, and by notes being thrown out of tune we learn how the atom is being treated, and

how it is behaving itself. The pitch of a tuning-fork alters if the fork is made to travel rapidly. If it be approaching us, the notes crowd upon one another, the waves shorten and the pitch rises. If travelling away, the waves lengthen out and the notes become flatter. So, light waves in the same way are thrown out of tune by the travelling vibrating atom. If it is moving away, then the coloured line is displaced towards the red. If it is approaching us, then the displacement is towards the violet. When atoms are moving in all directions, then the waves are displaced both ways, and the line broadens out.

Thus are we learning to read the beautiful cipher message from our new stars. Broad bands, indistinct at the edges, brighter in the middle, are produced by atoms travelling from us, sideways, and towards us, at speeds of hundreds upon hundreds of miles per second. In fact they are the message of the flaming, expanding orb that must result from the coalescence of the two fragments; clearly it would give us just such bands. The two superimposed lines are telling us of a body travelling hundreds of miles a second towards us, and of another flying from us. The lines are on the band because the atoms forming the nebula are travelling faster than the giant orbs themselves. One of the best determined measurements gave three hundred, and four hundred and thirty miles a second, as the speed of the two constituents of Nova Aurigæ. Here, then, is the full reading of the beautiful coloured cipher that came to us from that marvellous star. It would not be unfair to ask a student who knows nothing of impact to tell the kind of spectrum such a set of

bodies would produce. There is but one correct answer; and, if a student cannot give it, he cannot read the spectrum. Is not this piece of evidence of impact most convincing? As we proceed proof becomes overwhelming. On the theory of partial impact variable stars are produced in pairs. Are any such to be found? I sought in vain for an assertion of the fact; then I plotted some of these stars, and on my large chart some were so close, that, in especial cases, I could not put a needle through one without destroying another. "Can this be chance?" I asked my mathematical fellow-worker in cosmic problems—Mr Beverley, of Dunedin. Chance! certainly there is one chance in one hundred and sixty-two sextillions. Somehow, that one chance does not disquiet me. Of course, a variable star, unequally heated, tends to lose its variability by conduction, convection, and all sorts of agencies. Still, I have shown that quite a number of counteracting agencies may possibly retard this equalisation of temperature for perhaps thousands of years. In consequence of this tendency to equality, I did not expect to find numerous variable stars in pairs. Is there any evidence of the lessening of variability? It is overwhelming. Some stars are known to have been variable that are variable no more, and the variability of very many stars has diminished greatly. Besides the types described, there are all kinds of eccentric variables, as, of course, we should expect, for the field of possibilities of impact seems infinite.

Think of it—of the amazing variety of conditions! The bodies may be of the same, or of altogether different mass. They may have every variety of density; one may be dense, the other rare. They may

be as dead as the moon, or as fiery as the sun. They may be of totally different chemical composition, or approximately the same. One may be a star cluster, another a nebula, or star clusters and nebulæ may collide with one another. Perchance a huge dead sun may recurrently plunge through a group of dead suns and give us the extraordinary Eta Argus. The bodies may have every variety of impact, from a meeting full face to face to the merest kiss. Is there any end to the list of possibilities? I think not, and hence, not to weary my readers, I will try to describe the *modus operandi* by which that fiery kiss weds two giant orbs into a union that may last scores of millions of years.

CHAPTER VI.

DOUBLE STARS.

In 1877 the star appeared that sent my mind in quest of the stupendous agencies that must be working in the cosmos thus suddenly to produce a sun which in a year faded to a cloud of fire-mist. It did not cost an hour to learn what a scientific El Dorado I had struck upon. I saw that a graze was a force sufficient to cause burnt-out suns, Phœnix-like, to rise in wondrous glowing systems from the ashes of their dead past.

But not without long study and much aid from fellow-workers were the consequences of the graze revealed to me in the richness and complexity, the power and perfection of their action. So one must not wonder that the first thoughts of astronomers on these consequences should be somewhat vague. The following extract from Sir Robert Ball's article on "Double Stars," published last year in the Melbourne *Argus*, will show that not all the seed sown by the thousands of pamphlets and papers sent abroad has fallen on barren ground, although students of impact will see by the extract how very imperfect the conception still remains even in the mind of so great an astronomer:—

"Let us suppose that two of these globes, when bent on their voyages through immeasurable space, should happen in the

course of events to cross each other's tracks and to be hurled each against the other in a mighty collision. No doubt, I freely admit that such incidents must be extremely infrequent in comparison with the number of globes for which such a disaster would be possible. But these objects exist in such myriads that ever and anon the chapter of accidents will suffice to bring some pair of globes into collision, though as regards any two particular globes the improbability of their striking together would be quite as great as the improbability of the striking together of two specified rifle bullets in the air as they flew over a battle-field. But no one can deny that if, in the course of the battle, sufficient cartridges are discharged from both sides, this excessively unlikely thing to happen in the case of any particular pair of bullets, may yet happen in the case of some pair. We have the best reasons for knowing that throughout the length and depth of the universe it has sometimes occurred that globes, hurrying along with a speed far swifter than that of any rifle bullet, perhaps, indeed, a hundred times as quickly, have thus been brought into collision. One effect of such a collision is amenable to calculation. There is not the slightest doubt that it must be accompanied with the evolution of a stupendous quantity of heat. In fact, it is known that if a globe moving with the velocity which this earth possesses, were to come into direct collision with an obstacle equally massive, the quantity of heat that would be produced by the impact would be so vast that each of these mighty globes would not only be heated red hot, but would actually be transferred into what we may describe as a fire cloud. Under

ordinary circumstances the two stars would not come from exactly opposite directions, and thus strike each other directly; the blow must usually rather be described as a very serious graze. In such a case there would be an evolution of heat often sufficient to raise the whole globe from the extremely low temperature of space up to a state of vivid incandescence. After the collision the two objects would separate, each having conferred upon the other the glory of a brilliant star. The law of gravitation under all circumstances must assert itself These two objects, deprived of a large part of their original motions by the collision, would assume movements of a new kind, the guiding power of which would be found in their mutual attraction. Under such circumstances each of the globes would revolve around the other, just in the same manner as a planet revolves around the sun. It may certainly be admitted that we have never up to the present actually been witnesses of the process by which a pair of glowing suns have been brought into such remarkable association. But it will hardly be doubted that such collisions must have occasionally produced the results above described when we note the fact that there are in the heavens thousands, I might doubtless say many thousands, of pairs of stars, each of which revolve around the other, just as if their origin had been that which we have described."

Sir Robert Ball refers to rifle bullets meeting. I have seen the photograph of a pair of bullets fused together by such actual collision. What Sir Robert says is very satisfactory as far as it goes, but he does not seem to realise the very slight effects of the graze upon the remainder of

the orb. I have shown, by several lines of reasoning, that if the orbs were as hard as adamant their energy is a million million times in excess of the shearing force that is necessary to cut them; so that, wonderful as it may seem, the parts not impacting would not be greatly heated by the collision.

It will also be observed that Sir Robert Ball says such collisions have not been positively seen. But I have shown that the birth of a new star almost certainly results from collision. He says nothing of the middle body produced; yet without this middle body the stars would collide again and again, ultimately coalescing.

When I spoke to Proctor on impact, he readily admitted most of my reasoning as to what would result were a collision to occur, but was very emphatic as to the entire improbability of the event. But, at that time, photography had not revealed the amazing number of the stars, and the idea of dead suns was very vague; nor did he estimate the enormous deflecting power of the mutual attraction that suns would exert upon each other, thus tending to produce collision. Subsequently, in his "Large Astronomy," he discusses the possibility of double stars being formed from collision, and points out this difficulty of recurrent impact. He admits the pair would be wedded; but he imagines that at each anniversary the gorgeous ceremony would be repeated. If so, each impact would necessarily use up some energy, until, instead of marriage celebrations, the occasion became a kind of stand-up fight, in which the blows would continue to grow quicker and quicker while strength remained; then the great orbs would

coalesce into one huge nebulous bun-shaped sun.

Let us examine the agencies that render recurrent impact very rare. They are fully debated in my papers in the New Zealand Philosophical Transactions for 1880, under the heading Double Stars and Agencies Tending to Alter the Eccentricity of Planetary Orbits. But, since these agencies have missed the observation of scientists, they are not likely to be very easy to grasp. However, we shall consider some of them.

We understand how a partial impact leaves three bodies — the vast flaming nebula and the two scarred suns. We see how the nebula expands, overtakes the suns, and envelopes them. It overtakes them because they quickly lose much of the velocity they had at impact. The suns lose this velocity partly as they gained it, by mutual attraction; but the great central nebula at first also exercised immense retarding influence, so they do not retreat with the velocity of their approach; they are, as it were, tired with the tremendous exertion. If the colliding pair had been swift suns before the attraction commenced, possessing a great independent motion like the star 1830 Groombridge, they would still lose some of this motion by the graze, but not enough to wed them. Probably, as a rule, dead suns move faster than brilliant ones, as, doubtless, the brilliancy of suns is partly kept up by impacts, which necessarily destroy some of their motion. But if such a slow sun as ours were very slightly to graze another such sun the pair would not escape; the extra attraction of the nebula of coalescence would wed them, and they would come rushing back towards each other. Why, then, would

they not collide again? For this reason: —the nebula that entrapped them would be outside their orbit on their return, and so, instead of being pulled back to collide, they would keep at distances of millions upon millions of miles from each other. Our married suns are not fervent lovers; gravitation chains them, but they maintain the distance of respect. Their short experience of close contact was too stormy, too tremendous to be repeated. What would happen to the earth were our sun to lose half its mass? It would speed away and its orbit would be immensely enlarged. So it is with double suns; the central nebula loses its mass, and so the pair enlarge their orbits and do not collide again. This is not the only agency which prevents recurrent impact, but it is the most important.

Thus we have seen partial impact produce the star that fades into star-mist and two rotating wonder stars. We have also seen how the central nebula weds the two stars, and then by dissipating prevents their impacting again. We have now to ascertain how the characteristics of double stars correspond with the conditions promulgated in these papers. Obviously, the orbits would be highly eccentric. The stars would often be associated with a nebula, and sometimes for thousands of years one or both would be variable; also, from the fact that the metallic interior would well up, and form a vast molten lake, they would tend to be coloured, and have characteristic spectra.

Such are some of the deductions imperatively forced upon us if we consider that binary stars have been associated by impact. All are borne out by observation

in a most remarkable manner. Yet it was not easy to find some of the evidence; I sought more than two years before meeting any statement as to the variability of double stars. Then I came upon the work of the great Struve, and all at once obtained proof that variability is a remarkable characteristic of binaries. Struve had verified this as to twenty-five, and suspected forty more. Later observation goes to show how common the characteristic is. Colour and peculiar spectra are also characteristic. As to the association of nebulæ and double stars, Herschell says it is very striking, and one has only to refer to any table of the elements of binary stars to see the extraordinary high order of their eccentricity. Lastly, where stars are thick we should expect to find a high ratio of double stars, and such is the case; nearly all the binary stars are confined to the Milky Way.

Should the evidence here offered that Partial Impact occurs, and that it is an agent of tremendous constructive power, be insufficient to convince the sceptical, I must ask such, of their patience, to travel with me into the realms of molecular selective escape. I must ask them to consider the formation of star clusters and meteoric swarms, to investigate the evidence offered by modern photographs of nebulæ, to trace out the origin of the order manifest in the universe and solar system, and to glance at the wondrous interacting agencies which suggest that our universe is but one of many, and that the mighty cosmos, as a whole, is infinite and immortal.

There are other ways besides impact by which suns may become associated. Whenever three cosmic bodies come near one

another one of them has its velocity lessened. Thus, a comet approaching the sun may come near a planet, say, Jupiter; and if its line of direction towards the sun causes it to be nearer Jupiter when it has passed than when it was approaching him, the comet will lose more velocity than it gains, and travel more slowly. Hence it may not have enough speed to get away from the sun again, and will thus become orbitally connected. Such occurrences would happen rarely with suns; but may, however, have produced some binaries. Again, a star may plunge tangentially through a nebula, and be retarded enough to be unable to release itself; hence it would revolve about the nebula and plunge through it at each revolution. The friction would cause it to lose velocity, and this lessened velocity would make its orbit more and more circular; until, when the nebula shrank to be a sun, the two would form a binary star.

CHAPTER VII.

STAR CLUSTERS.

Marvellous as is the beauty of Saturn's rings, of Venus in quadrature, of those lovely cosmic flowers the glowing nebulæ, yet the wondrous star clusters, according to astronomers, eclipse everything else for brilliant magnificence. These groups of celestial gems may sparkle like diamonds of the first water, or they may shine with many a varied tint, some blue beyond the Oriental sapphire, some vivid green, or red, or purple. Some of the groups are all white; some, as in the constellation of our Southern Cross, are white, interspersed with red, blue and green stars; while the most wonderful of all the clusters, that in the Toucan, is of an exquisite rose tint. Then, the number of component stars is wonderful; in most clusters they may be counted by hundreds, in some there are many thousand independent points of light, every point of light a sun—perchance bearing a planetary system with it. What possibilities unfold themselves! Think of any one of these solar systems threading its way through the maze of the other suns! What vicissitudes it must encounter! For hundreds of years it might revolve amongst the densities at the centre of the system; then its orbit might be deflected, and for thousands of years it might travel towards the exterior of the cluster. As for the

sudden adaptations of natural selection on such a sun and its satellites, the changes from tropic to arctic during the great glacial epochs of the earth would be nothing in comparison. Then, again, how the heavens must alter in aspect within those wondrous coloured clusters, where in one part the emerald and the ruby enhance their mutual beauty, and in another the topaz and the sapphire outglow each other! Imagine oneself the inhabitant of a planet lit by a ruby sun and an emerald sun! Consider the brilliant pictures—and the shadows—every shadow chromatic, and every shadow double, one coloured red and the other green! But if these wonders seem too much for human imagination, we need not try to conceive the effects for the inhabitants of a planet within a coloured star cluster; only an infinity of omniscience could accomplish the task. Ten thousand solar systems performing a ballet dance, in which each movement takes ten thousand years! Contrast this with the dance of the ciliated bacilli on the microscopic slide!

The great Humboldt asked this most suggestive question: "How can these systems be maintained—how can the suns, crowding at the interior of star clusters, fulfil their revolutions freely and without clashing?" Do they revolve without clashing? The answer is: Almost certainly not. One of the latest new stars was in a cluster, and the brilliant point of light often noticed in such groups is doubtless the heated wreck of colliding suns. Every such impact strews the centre with gas which exercises a retarding effect upon the suns passing through it; every such collision lessens the motive energy of the cluster and helps to weld it together. But

I trench on the history of clusters—a long difficult matter, which must be told slowly and systematically. We are asking here: How did the galaxies of suns originate, and what force united all these giant orbs into magnificent concordant groups? My fellow-travellers must enlarge their patience, for I want to take them to heights of thought that few have scaled—to trace complex agencies, to follow the flights of varied molecules that would make intelligence reel with the mazes of their motion were it not for the wondrous order they observe, and to contemplate the interchanges of matter and energy. As we ascend in the research of grazing impact, we look out upon a series of problems so fertile in result, so infinite in potentialities, that our feelings are exactly the reverse of Alexander's: the student of impact will shed no tears over a conquered world; his sphere is boundless; in every direction new avenues of investigation are found and new fields of observation expand before his delighted vision. And although vicious specialisation will doubtless invade its domain when it is so unfortunate as to become fashionable, yet so wide is the basis of experimental science required for preliminary comprehension that this particular disease will have but slight scope. Of course, in a popular sketch, such salient ideas only will be indicated as shall serve to render the formation of star clusters generally intelligible.

I estimated that the colliding pair forming Nova Aurigae must have been respectively four thousand and eight thousand times the mass of our sun. A grazing impact of such a pair of orbs would consequently possess enough matter to make a

cluster of stars, and if we can show that the conditions for the formation are present, the problem is solved. I have suggested reasons for supposing that dark suns may have a higher average independent velocity than luminous orbs. Imagine that two such dead suns, with independent velocity, were to collide deeply. The nebula produced would be intensely heated, and would rotate. If two bodies like our own sun were to completely collide, the impact would not convert them into a nebula; but our sun is made up of different chemical elements, from the very light atoms of helium and hydrogen to the heavy ones of lead, gold and platinum. The collision turns the forward motion of the mass into a motion of the particles, that is, into heat. It would not matter whether the mass were all hydrogen or all lead, the rate of the molecular motion would be the same; but the lead molecules of the same speed as hydrogen would be more than two hundred times as hot. So, in a sun of mixed elements, immediately after impact the speed of the atoms would be the same and the temperature different. But mixtures tend to equalise temperature. Then the cool hydrogen gains and the heavy lead loses heat until they have equal temperature. Now comes into play the wonderful principle I have called molecular selective escape. We understand that a body which travels fast enough may leave a cosmic mass and entirely escape. Hence, when at the same temperature, light atoms may leave the mass and the heavy ones may not be able to do so. But if the central mass be very small then every molecule may leave the body.

All who have studied partial impact

know the fundamental thought of the whole theory is:—A small ratio graze would be as hot as a large ratio graze; the grazed parts would coalesce, and the velocity of the molecules would be so high that, if the graze were slight, the attraction of the mass would not prevent their escape and entire dissipation throughout space. This idea of gaseous escape, in its many modifications, discussed in my papers published nearly a score of years ago, is now taking its place in literature. Sir Robert Ball, who has succeeded Proctor as a popular exponent of astronomy, deals with the subject of molecular escape in a recent article on Mars. He says :—"But the chief interest that the principle we have laid down possesses is found in the explanation which has been given of it. That explanation is both so recent and so remarkable, that I am glad to have the opportunity of setting it forth, as it has an important application to Mars. The view of the subject here given is due to Dr G. Johnson Stoney, F.R.S., who recently communicated it to the Royal Dublin Society. Modern research has demonstrated that what we call a gas is in truth a mighty host of molecules far too small to be perceptible in the most powerful microscope. Each of these molecules is animated by a rapid movement, which is only pursued for a short distance in one direction before a *rencontre* takes place with some other molecule, in consequence of which the directions and the velocities of the individual molecules are continually changing. For each gas the molecules have, however, a certain average pace, which is appropriate to that gas for that temperature, and when two or more gases are blended, as in our atmosphere,

then each molecule of the constituent gases continues to move with its own particular speed. Thus, in the case of the air, the molecules of oxygen, as well as the molecules of nitrogen, are each animated by their characteristic velocity; and the same may be said of the molecules of carbonic acid, or of any other gas which, in more or less abundance, may happen to be diffused through our air. For two of the chief gases the average velocities of the molecules are as follow:—oxygen, a quarter of a mile per second; hydrogen, one mile per second. In each case the temperature is taken to be 64° C. below zero, being, presumably, that at the confines of the atmosphere. It will be noticed that there is a remarkable difference between the speeds of the two molecules here mentioned. That of hydrogen is by far the greatest of any gas. We may now recall a fundamental tact in connection with any celestial body, large or small. It is well known, that with the most powerful pieces of artillery that can be forged a projectile can be launched with a speed of about half a mile a second. If the cannon were pointed upwards the projectile would soar to a great elevation, but its speed would gradually abate, the summit of its journey would be duly reached, after which it would fall back again on the earth. Such would undoubtedly be the case if the experiment were made on a globe resembling our own in size and mass. But on a globe much smaller than the earth, not larger, for instance, than are some of the minor planets, it is certain that a projectile shot aloft from a great Armstrong gun would go up, and would never return. The lessening gravitation of the body would fail to recall it."

Thus has the idea of Molecular Selective Escape become public property.

An obvious result of this selective action is that the coalesced mass is robbed of its light gases. Thus, at the same temperature, the mean speed of hydrogen is four times that of oxygen, about seven times that of iron and fourteen times that of lead. So, after a time, the elements rushing on into space will sort themselves into concentric layers: the helium, hydrogen and other light gases speeding ahead; the lithium, nitrogen, oxygen and so on following in the order of their atomic weight. But oxygen, although not heavy, has great affinity for silicon and many metals, forming with them non-volatile and coalescent molecules. Hence, as the expanded mass cools, this chemical action sets in; and a very rare, very stupendous rotating luminous dust globe—or, perchance, dust shell—is formed. Gradually, as with rain and hail, coalescence of particles takes place. If there were no rotation, this dust would coalesce into a sun; but, with rotation, such is not necessarily the case. The particles will be attracted to the centre, but their tangential motion will make each move in an orbit. The particles will continually cross each other's paths, coalescing and growing larger and larger; but, as selective escape has taken everything of the nature of nebulous matter out of the system, there is nothing to offer resistance to these growing particles; they become fewer in number as they increase in size, and the huge mass of glowing dust is slowly converted into a star cluster.

It is scarcely likely that there can be any definite order as to the orbits of stars in a cluster. The perturbations throughout

the group must be so tremendous that impact should be frequent; and it is possible we might thus study every peculiarity of impact were it not for the difficulty in getting detached spectra.

As to the future of star clusters, almost certainly impact will cause the central condensations to increase until the temperature will volatilise some of the suns, and this vapour will be a retarding trap for those suns that pass through the centre. Ultimately, this centre will become a huge flaming sun, with a vast system of dead suns, that will one day be giant planets.

How rich are the possibilities of the cosmos! The pendulum of eternity sways, and a pair of dead suns collide—each, possibly, with innumerable satellites, that, after the collision, continue orbitally around a huge fire-mist. Then the fire-mist cools and coalesces, and becomes a star cluster. The stars of the cluster collide, again volatilize, again coalesce and become one vast sun, with the cooling outer suns—now planets—teeming with such lofty life as evolution may produce on their immensities during the thousands of millions of years of action that but complete the swing of eternity's pendulum!

We have considered impacts that may produce star clusters. It is easy to realise smaller collisions producing the dust swarms, which, under the influence of the heat of internal friction, of reflection of solar light, and of electricity, occasionally adorn our skies with the waving plumes of beautiful cometic visitants.

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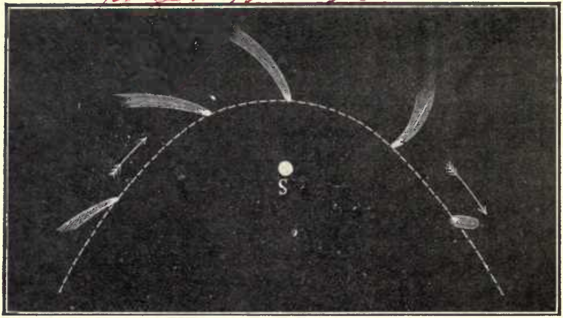

FIG. 12.—DIAGRAM OF COMET'S ORBIT.
The above diagram illustrates also the direction of the tail

FIG. 16.—A CLEARLY CUT SPIRAL IN CANES VENATICI.

CHAPTER VIII.

NEBULÆ.

Leaving the Milky Way, with its hundreds of millions of blazing suns, its crashing orbs, its multiple stars and its gem-like clusters, we pass through vast spaces of comparative emptiness. Then, as we approach the poles of the galaxy, fresh objects become visible. These are the glowing nebulæ—commonly revealed by the great telescopes of our astronomers as spherical masses of luminous cloud. Sometimes they show shapes of exquisite symmetry; and, as the power of observation increases, so the number of nebulæ showing structure increases also. The forms thus made manifest are very varied: long, delicate spindles; shorter spindles with spirals at their centre; exquisitely perfect double spirals; nebular rings, sometimes with light, gauze-like caps at the poles of the rings. Then, there are double and multiple nebulæ, double nebulæ associated with spindles, and many other combinations; while, besides these nebulæ at the poles of the Milky Way, there are the planetary nebulæ and the huge irregular nebulæ of the Milky Way itself.

I have already mentioned how the varying mechanical conditions of partial impact would lead to just such forms being developed when the originally impacting

bodies were nebulæ so rare that collision would occur without explosion. Let us try to imagine the origin of these huge globular nebulæ, and of some of the varieties of forms possible to be produced by their coming into contact with one another. In my article on the origin of the visible universe, I shall try to show that at one time both of the galactic polar regions were continuous masses of nebulæ of extreme tenuity. Any cosmic body that passed through such gas might be entrapped; the heat produced by friction would tend to volatilize it; molecules would be attracted towards it; thus as the body travelled, it might leave an expanding train that would make a cometic nebula, although cometic nebulæ may be formed in other ways. All irregularities in gravitating matter tend to accentuate themselves; hence, the volatilized body gradually attracts nebulous matter about it, and a globular nebula results. Attraction acts everywhere; and, where there is no counteracting agency, it generally welds matter into a sphere. Molecular attraction unites the particles of water into the dew drop, whose liquid form tears to pieces the interwoven colours of the sunbeam, and sends them forth in wondrous tinted shreds. Attraction makes the solid earth a sphere, slightly flattened by its own counteracting spinning motion. So attractive action on diffused nebulous matter aggregates it into gigantic roughly-rounded masses, the original motion modifying its form.

But, doubtless, all these nebulæ retain some of the motion of the original body that commenced their formation, and are consequently travelling in space. Sometimes they must be in one another's path,

whilst their own gravitating force urges them towards one another. Thus they collide. The agencies that apply to the impact of stars apply also to nebulæ, but are much modified. I had to ask your patience when we traced the flight of various molecules—now we enter on a new series of motions. We are not considering how the individual atoms sort themselves; we are following the transformation of enormous masses of luminous gas into the beautiful celestial fire flowers that compose the bouquets of the universe.

Our two globular fire clouds are impinging upon one another. The cooler outer portions inter-penetrate, the encounter of the molecules makes them vibrate, and the waves so set up in the ether give us increased luminosity. The nebulæ may move many hundreds of times faster than a rifle ball; yet so enormous are these bodies that the impact may take hundreds, perchance many thousands, of years. As they pass each other the colliding gas forms a luminous spindle between the two nebulæ. Herschel has given us drawings of these vast globes, with spindles between them in all stages of formation. In every case the rare outer atmosphere of each nebula plunges deeply through the other mass, and there is a lack of balanced momentum on either side; so that, as the colliding nebulæ go on their way, trailing the spindle behind, they leave the centre of the spindle in a state of whirl. And so, as each of the ends of the spindle travels after its retreating nebula, gradually the motion of the centre converts it into an expanding double spiral.

Although the life of a man may not permit him to trace in its full history such a wondrous nebular evolution, yet, so rich

is the mighty cosmos that, by means of photography, every stage may be studied simultaneously. Think of a sensitive photograph plate being presented for many hours to the same object—a plate that, in a thousandth of a second, would photograph a flash of lightning! Imagine this plate fixed in the focus of one of our great light-gathering telescopes, kept by accurate clockwork, following the apparent motion of the nebula; then some idea may be formed of the tremendous power of our modern research! The great nebula of Andromeda is a spiral, that of the Lion shows the spiral at the centre, then in gradually developing spirals we have that of Pegasus, of Virgo, of Canes Venatici. The "Photographic Annual" for 1895 (pages 234-235) describes Dr Roberts' discoveries of spiral structure of nebulæ where the visual observation of Lord Rosse and Sir John Herschel entirely failed to discern any such structure. It also describes new spiral nebulæ of great beauty, and other structures never even suspected before in nebulæ. But now comes the part interesting to students of impact. Dr Roberts, at the meeting of the Royal Astronomical Society in May, 1894, suggests, in explanation of these convolutions, that the nebulæ were formed by streams of meteors which came in contact whilst travelling from opposite quarters of space, the collisions of their margins producing the spiral motion. Again, he says of another nebula: "There is a considerable amount of structure in the nebula, which seems to be assuming the spiral form, as if there had been a collision in one half, which had the effect of closing together the nebulous mass and distorting its form." Thus,

although no astronomer appears to have taken the trouble to read any of my papers carefully enough to grasp the deeper principles promulgated in them, there is growing up a belief in the occurrence of Partial Impact, and a superficial appreciation of some of its effects.

But we must leave the spiral nebulæ and pass on to the wonderful ring nebulæ, which, from their analogy to our visible universe, lead us to the most important and far-reaching of all the many subjects the theory covers. Hitherto we have dealt with impacts in which, as a rule, the original bodies have separated after the impact; but, obviously, bodies may plunge so deeply into one another that they never part again, and to a collision of this kind I believe that annular nebulæ owe their existence. It is not to be imagined that a solitary worker in the vast field of impact can think of all the conditions of such complex phenomena, all the agencies set at work by such conflict of forces. Still, I will at least try to tell of some of the forces rendered active by a grazing but almost complete impact of nebulæ.

Imagine two huge gaseous globes plunging through each other; as they close in from opposite directions we realise that a stupendous whirl must be set up. But another action is to be traced. Obviously, the mere closing-in of the colliding nebulæ must produce pressure; but compression produces heat, and this in its turn produces more pressure; so that at the centre of the mass there is an enormous expanding force. Where in this whirling mass can it find relief? Certainly not in the directions in which the two nebulæ are closing in upon one another,

not in the plane of rotation; but there is no opposing force in the direction of the axis, and in this direction the pressure produces motion. The coalesced bodies are now a kind of huge mortar open at both ends, from which are projected in either direction torrents of gas. Pressure commences the outrush of gas and molecular escape finishes it. Thus is the centre cleared out of the huge, bun-shaped rotating nebula, and it becomes a ring; so that annular nebulæ should for a time be accompanied by a gauze-like material that, seen endways, seems to stretch across the ring; seen edgeways, appears a diffused film in the direction of the axis.

Of the great irregular nebulæ of the Milky Way I shall not treat. But I must here say a word on the planetary nebulæ of the same region. The reader fully understands how a grazing impact strikes off a brilliant spark that flashes for a cosmic moment and is gone. We have tried to realise the explosion, an explosion ten thousand times more violent than if those giant suns were solid dynamite. We have watched the outrush of molecules speeding past one another, and sorting themselves: light active atoms outdistancing the others and dispersing in space—intermediate atoms following but not necessarily into outer space; they may travel only so far as to form a huge hollow shell of gas, and then, slowly losing velocity, may so remain for thousands of years, forming the planetary nebulæ which are the astonishment of astronomers. In describing these shells, Herschel's amazement at what his acute observation and reasoning have shown him, is palpable and undisguised; and he tries to account for them by every other explanation he

can conceive of; but none will do. Yet, on the basis of impact, the formation of such shells is so obvious, that if they had not been discovered we should search for them. Some of these planetary nebulæ have stars at the centre; clearly, the heavy molecules would coalesce by attraction and sometimes form a central sun; not necessarily a sun, they might form a star cluster, or, perchance, an invisible swarm, a member of which might occasionally collide and blaze forth as a temporary star.

The possibilities of even a section of the subject seem limitless, but this much is manifest—the wonder and beauty of the fields of research are as sublime as their expanse is magnificent.

CHAPTER IX.

THE SOLAR SYSTEM—ITS ORIGIN.

We have seen how a star cluster may originate and may become an incipient sun with satellites, whose orbits are at all angles. It is also easy to realise how a nebula may entrap bodies which, on the shrinking of the nebula into a sun, may become planets revolving in all directions. But without the idea of impact to originate a common rotation, it is difficult to understand the evolution of systems such as the one of which our earth is a member—a system in which the sun and almost all of its satellites rotate, and all the planets revolve, in the same direction and roughly in one plane.

The exquisitely ingenious hypothesis of Laplace, of the release and coalescence of nebular rings, has fascinated mankind for generations; and although its basis is gone it leaves much fertile thought. The same may be said of the meteoric hypothesis of Lockyer and Proctor. The insuperable difficulties afforded by the dynamical theory of gases as against Laplace's theory does not apply to the meteoric idea; but, amidst the wondrous order of the system, the irregularities in the directions and orbits of the moons and planets, and of their axes, are too great to be accounted for on the meteoric hypothesis, so that although it was once fairly

well known, it has almost passed out of literature. The ground is, therefore, clear for a new hypothesis, could a reasonable one be found.

It is a tremendous subject to plunge into, but it is no use to stand shivering on the brink when we have made up our minds for the venture.

It seems to me, then, that the sun is the result of the collision of two bodies that have fused and become one, whilst the planets existed before the collision occurred. The marriage of the two bodies that made up our sun was not a kiss followed by an almost eternal union of distant respect. It was a close embrace, in which the two became actually one.

The planets are not the offspring of the union, they are stepsons and daughters. Whether all belonged originally to the one, or were divided between both parents, it were hard to tell, perchance we may never know. Possibly the four inner planets may have belonged to the one, and the four outer to the other. They each form a set, the members of which have a close resemblance to each other; yet each group is so unlike the other group, that the two groups may not be related. Still, when we come to consider the evolution of such a system, it seems almost inevitable that some of this contrast of character between. the inner and outer planets must have come about during their growth and training, and may not be an hereditary distinction, so that much latitude of conjecture remains which further research may narrow. Thus, generally then, let us imagine the birth of the solar system.

Two vast globes are rushing in upon one another, one or both attended by satellites.

Any of these satellites that plunge deeply into either body are at once burnt up—as the meteors of a November shower are dissipated by our atmosphere—but all do not so plunge. As the great globes impinge upon one another, some of the satellites are carried forward and escape the general conflagration.

The solar system does not look as if it were produced by a partial impact in which a portion of each globe passed forward into space. The orbs, probably, plunged deeply into one another, and the parts not actually meeting were carried forward as huge tongues of fire that whirled around the general mass and were absorbed into it. All the agencies of an impact would be at work—intense heat, axial pressure, selective escape and rotation. But the enormous attraction modifies all these agencies. The gravitating power is not small as it would be were a portion struck from each body. Both the entire bodies have coalesced, and the mutual attractive power neutralised the expansive effect of heat, and stopped the escape of molecules, except the lightest and those favourably situated. Doubtless there never has been a cosmic impact that did not strew space with countless wondering molecules. But in the origin of the sun this was not a large factor. The impact caused a whirl that swung the materials of the bodies into a huge bun-shaped rotating nebula, possibly always very dense at the centre, but very rare at the exterior, and probably extending beyond Neptune; at least, the very circular orbit of that planet suggests that it was so, although this is not necessarily the case. The tidal stoppage of its rotation

may have greatly enlarged its orbit, for we must remember that although tidal action would be very small at Neptune's distance, yet it would not take much work to push the planet further away from the sun. Anyway, that is a question mathematicians may probably answer. Certainly, if the solar system was formed in this way, the outer margin of the nebula extended to an enormous distance.

Let us gather up our ideas. Two bodies with satellites have collided, have coalesced, the non-coalescing parts swirling around each other, and this onward motion, combined with the expansive effect of heat, and its other result—molecular escape—has converted the two bodies into a nebula. The original satellites that formerly revolved without any order are swung forward by the onward rush of their parent orbs. Some are dissipated, but some escape; those cannot fly entirely away—the attraction is too strong; hence they revolve in highly eccentric orbits. Had they been originally at rest they would have been thrown into a single plane and would all revolve one way; and in their passages through the nebula would all tend, as Laplace has shown, to rotate in the same direction. But they were not at rest around their central body; they revolved, and probably rotated. All these motions would tell in the final result, and fully explain all the irregularity of the system.

This, then, is an account of the possible union of the two bodies that formed the system. The education and training of the planets, &c., is a matter of some difficulty. Much of their schooling has already been told in detail in earlier papers.

But the complexity of the training process tends to become bewildering, so we will only give a very general glance at some of the agencies that have converted that apparently awful chaos of fire and conflict into the order and method that now remain.

In the eye of the mind we watch the flight from the central fire of the planets and, perchance, countless smaller bodies. We watch the gigantic fire mist whirling and expanding until it is many hundreds of millions of miles in diameter. We see the planets gradually lessening the speed of their flight, and presently commence their fall back towards the centre. They plunge deeper and deeper into the fire mist, and all the gas outside their orbits has no influence in causing their return. Hence the orbits become more circular. But in the nebula the body becomes heated and expands, gathering the gas of the nebula towards itself. The bodies cross one another's path, and will often coalesce. Almost every such coalescence will tend to make the orbits more circular, to cause the rotation of all the planets to agree in direction, and the axes to become more perpendicular to the plane of the orbit. It would also bring this orbit into the plane of the general rotation of the nebula. Any planet that came near the centre would be intensely heated, and hence there would be a tendency to lose light molecules; whilst, on the other hand, this body would tend to pick up the heavy molecules that selective escape would have left near the centre of the nebula. Thus, the inner planets would tend to be small, and to consist of dense material, and the outer planets large and less dense, exactly as we find them in the solar system.

The giant planet Jupiter has probably

been largely formed by impact and accretion, owing to its being in the centre of the storm of meteors that would be produced by coalescing molecules, &c., and hence its axis is very upright. I think Proctor was the first to point this factor out. The moons were probably bodies entrapped by the planets when nebulous. The orbits of the moons have probably increased by tidal action; much of their potential energy of expansion would become energy of rotation, and this by tidal action would turn into potential energy of distance from their planet. I cannot believe that the belt of the minor planets, or the meteors constituting Saturn's rings, could have been present when either the solar nebula extended beyond the planetoids or Saturn's volume extended beyond his rings. I believe in one case a planet, and in the other case a moon, has been blown to pieces by a body plunging into their mass. Those who have argued against this origin by explosion, have overlooked a number of agencies that have been effective in giving the present orbits to the planetoids.

Of the origin of the very imperfect order of the distances of the planets, called Bode's law, I have given a full account in former technical papers, but my space does not permit me to discuss it here. Enough has been said to show that there was a vast series of agencies at work, tending to give the wonderfully majestic order to the system of which our earth is a member.

We have glanced at the apparent chaos of original and acquired motions from which, as a skilful potter gives symmetry and beauty to a shapeless mass of clay, the ruling power of the cosmos has given life and rhythm to our system. The

storms have been subdued, and the flames quenched which gave the planets their long baptism of fire, and sorted the materials for their constitution. It is like a fairy tale to trace from the original terrestrial ball of fire the wondrous agencies that selected its material, wrinkled its solidified crust, laid its surface down in layers, kneaded and crushed those layers into mountain chains and immense valleys — gradually to be filled with liquid as the cooling earth allowed the acid vapours and steam to condense as salt water; then to watch the altered eccentricity of the earth's orbit putting into play the physical forces that, during the great glacial period, alternately covered each hemisphere with a vast ice cap extending far down into temperate regions. Then, again, it is a poem to trace the gradual absorption of the poisonous gas, carbonic acid, and see its carbon combine with other elements and clothe the earth with verdure, whose extent is revealed to us in the vast carboniferous beds of stored energy that we now use to drive our mighty engines. 'Tis indeed a story of wonders to see that verdure partly give place to animal life, and trace the long line of evolution that has culminated in man. But all this is of the earth earthy, and belongs not at all to the story of the wondrous stars that it is at present our duty to tell.

CHAPTER X.

THE ORIGIN OF THE VISIBLE UNIVERSE.

But yesterday, according to the swing of eternity's pendulum, the universe as we know it did not exist. We perhaps should say our universe; for, though the word in its original meaning applies to the entire contents of all space, it has come to be associated with the galactic system only; there being much reason to believe in the existence of other corresponding systems, the collection of all these universes making up the infinite cosmos. The thought capacity of the human brain is marvellous, but finite; we speak of the infinite—of the eternal—but we cannot conceive them. We know that time, and space, and matter, and energy are; of their whence and their whither we cannot know. We look, as it were, through a curved tunnel, in which the future is a repetition of the past; what we see is simply one phase of an eternal rhythm. But whence came our universe? And what existed before it was? Does the curve wherein we dwell permit reply to these tremendous questions? I believe it does. With form so definite and arrangements so orderly, we may trace some history of the past and some promise of the future.

Space is probably very imperfectly filled. In the distribution of matter our universe is comparatively crowded; yet think of the

emptinesses within our solar system, and of the distance between it and the nearest star! Gravitation tends to clear space of matter and aggregate it; the motion of wandering molecules tends to take them to the empty parts of the cosmos which gravitation has drained, again to occupy them, and again to initiate the formation of new universes — perchance huge agglomerations without any kind of arrangement, universes of the first order, as I have called them. I shall offer suggestions regarding these vast shapeless masses in my next article. Our universe is of a higher evolution; it is full of order and symmetry. The system consists not only of the immense belt of stars—the Milky Way—but also of the two caps of nebulæ which — as depicted on the celestial globe—cover the poles of the galaxy. But let astronomers speak for themselves as to its constitution. Sir J. Herschel, who has studied star distribution more than any other man, says that the mass of stars is generally flat, of small thickness. He also says that the number of stars visible in his telescope in the Milky Way numbers about eighteen millions, and about two millions in the remainder of the celestial vault. Struve published a list of stars in which he showed that in equal areas there were 4¼ at the poles of the galaxy to 122 in the galaxy itself. Proctor, who discussed the facts very fully, after showing that star clusters essentially belong to the galaxy, and that as we pass from that great circle we go through regular stages of irresolvability to the galactic poles, and there find the nebulæ are completely irresolvable, says:—"I believe that cause may he assumed not unreasonably to be the

difference in the circumstances under which the galactic and extragalactic nebulæ have reached their present state." Again, in respect to the nebulæ at the poles of the Milky Way, Proctor shows that every theory of their existence is ridiculous, "unless we concede that the nebulæ belong for the most part to our galactic system." The splendid charts and sketches by Sydney Waters, as well as those of Proctor and Newcombe, show strikingly this most remarkable arrangement.

Sir William Herschel states that any sound theory of the universe must account for the peculiar arrangement of the nebulæ. Proctor, in speaking on grounds of probability, says:—"Where the results are in direct contact, the rich regions for one order corresponding to the poor regions for the others, and *vice versa*, the two orders of objects belong to one system," and again says that he knows of no single reason for supposing these nebulæ to be external galaxies. That nebulæ are not external galaxies is proved from the facts recorded by Schmidt, Hind and others, that nebulæ have been observed to vary and disappear, which is clearly impossible with a galaxy like our Milky Way. I will give only one other extract from among a large number. It is from Proctor on "The Universe," which is wholly devoted to demonstrate these conclusions. "The phenomena I have been discussing seem to point to conclusions very different from those which have been usually accepted respecting the visible universe. Instead of separating the stars and nebulæ into distinct systems, or rather of looking on the stellar system as a member of the system of nebulæ, we

seem compelled to look on almost every object visible, even in the most powerful telescope, as a portion of one system, which comprises within its range simple, multiple, and clustering stars, irresolvable nebulæ, gaseous bodies of symmetrical and unsymmetrical figure, and in all probability myriads of other forms of matter as yet undetected."

Let us attempt to trace out the evolution of such a system. In describing the origin of annular nebulæ an effort was made to show how two globular nebulæ by tangential coalescence would produce a ring. Now we shall try to realise how two vast globular universes might plunge through one another, and by centrifugal motion, produced by their opposing onrush, be swung into an irregular ring of double spiral character. The two primitive universes were possibly more compact than our own universe is now, although there was probably much irregularity in distribution. There would be suns, nebulæ, star clusters and other systems; but they would probably contain much more helium, hydrogen and other gaseous elements than our universe does at present. Whilst the two gigantic masses closed in upon each other during millions of years, impacts between the various nebulæ, the suns and other systems, would be of increasing frequency. The centre of coalescence would thus gradually become gaseous, and the average temperature of this part would steadily increase and produce great pressure. This pressure would tend to expand the gas. Let us try to understand with what result. The two universes are each moving forward, and are partially in impact, whilst the remainder of each travels on, not, however, parting company,

but extending vast distances into space. Yet the increased attraction resulting from coalescence will not permit more than a few suns and other bodies with high original motion to escape altogether. Hence, the leading parts travel in a curve. Thus we should have a universe roughly double spiral in character, hot and condensed at the centre, and tending to a general rotation; whilst all the original motion of suns and systems would tell as factors in the resultant motion. But groups of stars similarly situated would tend to take a common direction, and produce the streams and sprays of stars and the community of motion of adjacent stars that have been pointed out by astronomers as so very characteristic of our universe. The impact producing the universe would not necessarily be in the least degree paroxysmal to any of the outer suns and systems; they would not even tend to be heated; dead suns would remain so, and other suns would lose heat and grow old. But at the centre of the vast system everything would tend to become gas under pressure—pressure acting in all directions, but finding relief most easily in a direction axial to the general motion. This outrush would cover the polar regions with wide nebular caps. The motion commences by pressure, but is continued by radial molecular activity, to be gradually stopped by the attraction of the whole universe. But another remarkable principle comes in: The pressure at the centre gradually lessens by the escape of material, yet the remainder is still hot, whilst the central attraction has lessened greatly; consequently, molecular escape may permit every molecule to follow the polar nebulæ,

and leave the central mass almost bare of matter.

It is probable that originally the polar caps were of continuous nebular matter, that, as already described, became aggregated into globular nebulæ by the passage of errant bodies through the gas. Much of this diffused gas may still remain —invisible to the telescope—but possibly to be detected by a very powerful photo-spectroscope. Proctor, discussing the origin of the polar nebulæ, says: "They may have been formed through the influence of the same principle which makes the centrifugal force near the poles of a rotating globe less than that at the globe's equator."

It will be observed that both regarding the solar system and the universe, coalescent impact of two complex bodies has been suggested. In the case of the universe, an axial pressure has been assumed as accounting for the polar nebulæ; yet, in the case of the solar system, no such suggestion has been made. Probably, however, gaseous matter may have so covered the poles of the solar system; but a large number of agencies are at work tending to produce modifications in every occurrence of impact, and it will be for future mathematical physicists to determine where one tendency stops and another begins. It may not be out of place, even in this popular account, to give some mathematical conclusions regarding impact. It is demonstrable that an infinitely diffused nebula, condensing into two solid bodies at infinite distance, has lost half its potential energy, exactly as much energy as is available by their attraction bringing the two bodies into impact; therefore, this

attraction, in a complete impact of dense bodies, is only half the energy necessary to make a nebula. Secondly, with a pair of bodies such as the sun, it can be shown that the energy of their attraction is only sufficient to expand them to the sum of their diameters. Hence it will be seen that an ordinarily complete impact of suns cannot produce a nebula, while partial impact can do so.

Let us retrace our steps. Two universes, roughly spherical in form, consisting of nebulæ, suns, &c., come into grazing impact and whirl around each other: all the original motion of each universe as a whole, and also of all the constituent members, tending to give irregularity to the final result. The parts coming into actual impact are gradually volatilised, and, by the pressure, the gas is projected axially, and covers the poles of the galactic ring with nebulous matter. It would seem probable that the onrush of the stars from each of the original universes would furnish two condensed regions. In accordance with this view, Proctor says:—"The stars of the first six orders are gathered into two definite regions—a northern and southern—so markedly that the distribution of stars within these regions is richer than the distribution over the rest of the heavens in the proportion of five to two."

Does not the constitution of the universe, given by astronomers as the result of their observations, agree in a most remarkable manner with that deduced from an assumed grazing coalescence of two previously existing universes? All through our universe the spectroscope reveals identity of matter and community of motion. Observers find a most wonderful contrast of character in different parts of the

heavens; yet, they say, the contrasting objects are related. The mode of evolution suggested by partial impact shows the nature of this relationship; shows why there is community of motion in adjacent stars or star drifts; why there are streams and sprays of stars; shows the origin of the galactic belt, why temporary, variable and double stars — why star clusters and planetary nebulæ are there, whilst other regular nebulæ are mostly at the poles of the ring. Whence comes such amazing correspondence between the constitution of the universe as given by astronomers, and this series of clear deductions from a probable cosmic occurrence? Does it not seem to suggest that, just as natural selection—including sexual and intellectual selection—is the agent of organic evolution, so impact, in its many varieties, is the agent of cosmic evolution? It may be that the theory of impact is indeed what a critic has styled it: "A master-key to the mystery, the greatness, the splendour, the multitudinousness and the variety of the heavens."

CHAPTER XI.

THE IMMORTALITY OF THE COSMOS.

Towards the close of last century Lavoisier's brilliant investigations demonstrated the indestructibility of matter. The great Frenchman proved—by the application of the balance—that nothing material can be lost; that, for instance, fire may cause apparent annihilation; but the atoms which existed before exist still, locked in new combinations. For fifty years this scientific achievement outshone all others, so that immaterial nature passed almost unnoticed, until our English Joule measured the changes of working power—energy we call it. Then another fundamental truth revealed itself. Energy, the imponderable entity of the cosmos—protean as thought—was found to be as indestructible as matter. In the face of this discovery the materialism of science was vanquished for ever.

Then the quantity of this energy—pouring in ceaseless torrent from the sun—was measured, and its origin was investigated. Answers more and more satisfactory were given, and, lastly, it was shown that the heat developed by the contraction of the sun suffices to account for solar radiation for tens of millions of years. Next the questions arose: Where is all this energy speeding to? Even that which falls upon

the earth escapes again into outer space. Will the sun send forth all his heat to the dust of infinitude? And, while cooling—with fleeting flashes, as planet after planet falls towards him—what evil fate is in store when he shall have devoured all his children? Will everlasting night encompass the burnt-out orb? It seems it must be so — that even collision with another sun will only postpone the period of death. Here let us try to understand Lord Kelvin's great generalisation, called the dissipation of energy. The laws of heat suggest that every hot body in the cosmos is cooling, and, by lost heat, will warm the cool bodies until all matter is at one temperature. In like manner the laws of gravitation suggest that all bodies will aggregate into one vast orb, thus reaching a state in which life, as we know it, will be impossible. The universe, probably having begun as diffused gas, will end as solid matter.

Is there any mode of escape from this conclusion of universal death? Rankin and Clausius have pointed out possibilities that seem to promise a less melancholy result, but Lord Kelvin has demonstrated their insufficiency. Herbert Spencer—in a magnificent passage in his "First Principles"—shows how impact may revivify; but the method he suggests fails on the score of equivalent energy, and physicists consider it no longer. Possibly there is no single physicist of eminence that does not —willingly or unwillingly—admit the logic of Lord Kelvin's argument. But it may be that—in coming to this belief in universal death—some agency has been overlooked. Is there any means by which low temperature heat may become energy of a higher order? Are there any forces at work to

diffuse as well as to concentrate matter? I believe both these questions may be answered affirmatively. The road of reply is definite and unmistakable, but entangled and circuitous; those, however, who will take the trouble to follow it will find it as beautiful and wondrous as it is difficult.

Space is dusty; it is a fog of wandering meteors, errant comets, extinct planets, and dead suns, with free molecules of gas travelling in all directions between the denser matter. Light penetrates this fog for millions upon millions of miles, but in time it is stopped. Thus all radiation may fall upon the dust of space and warm it. Heat is a motion of molecules. Gradually cool a gas, its molecules lose speed. Let molecules travel from bodies, the attraction of the bodies makes the molecules travel slower—in other words, cools them. Let a slowly moving molecule of hydrogen touch a warm particle of cosmic dust, it will bound off again carrying away the heat, exactly as in a radiometer: the heat of the solid body is changed into motion of hydrogen, giving the gas a fresh start on its journey.

The further a molecule is from matter the slower it travels; it is slowest of all in the most empty parts of space—that is, it lingers longer there than anywhere else. If particles are moving indiscriminately in all directions, and tend to linger anywhere, in that place they will accumulate. Therefore, freely moving gas tends to accumulate in the empty parts of space, and this gas originates new universes. This is the function of such light gases as hydrogen and helium, and perchance of gases lighter still. These minute molecules—these projectiles that selective escape has

set free from impacting bodies to travel with incredible velocities—they are cosmic pioneers, filling the parts of space left empty by shrinking universes. But not only do molecules travel quickly; cosmic bodies sometimes do so likewise. The star 1830 Groombridge is flying through the universe at the inconceivable speed of two hundred miles a second. It will probably fly completely through our universe—the chance of its striking another star is exceedingly small—and will travel into those vast gas-filled regions whose friction will slowly stop it, and heat it, and entrap it.

Thus, gas-filled space is a trap for wandering bodies. Gradually the mutual attraction of the entrapped bodies tends to coalesce them, to condense the gas about them, to diminish the volume and increase the density of these incipient universes. Such universes I call primitive universes—universes of the first order. They are nebulous universes, made up largely of light molecules, continually entrapping bodies made up of heavier molecules. Then, by mutual attraction, these primitive universes collide; and, as a result, selective escape sends some of the light molecules on their journey again, once more to play the part of pioneers, whilst the dense elements aggregate into suns and systems. Continually are the older universes thus drained of the light gases. But another remarkable principle comes into operation. As already mentioned, three bodies never pass near each other without a permanent relative change of velocity. One may gain speed sufficient to send it out of the universe it belonged to. And were two primitive universes to collide and become one, before that one reached its densest state,

it would probably—by many agencies—have sent half its matter wandering into outer space, free from its gravitating force. It is certain our universe is not a primitive universe. Whether its parents were of the first order, or had already collided and attained definite form, I cannot say. The evidence suggests that our universe, as such, is in its infancy; but that probably its parents were of the second order. Possibly, when more is known of its character by later thinkers, they may be able to speak decidedly regarding its antecedents.

Has this series of agencies been made clear? If so, the reader can perhaps picture the innumerable wandering molecules set free by cosmic bodies—the dust of space—the movements of radiant energy constantly pouring into space tending to warm that dust; the slowly moving molecules being struck by the vibrations of heated molecules and bounding off again to lose motion by further travel. He will realise the crowding of molecules in those empty spaces where molecules linger, and the gaseous nebula so formed being a trap for wandering bodies set free by the interactions of three bodies—the attraction, the shrinkage, the final coalescence into primitive universes in which there is practically no definite structure, no recognisable order; then the grazing impact, that by the rotation set up would whirl the two huge universes into one, with systematic structure and order. I formerly imagined the Magellanic clouds might be primitive universes, but the wonderful photographs of Mr Russell have clearly demonstrated such a definite spiral structure that it appears evident they are of a higher order. Their very condensed character also favours this view.

Thus, in contradistinction to the theory of dissipation of energy, partial impact and molecular selective escape declare the cosmos as a whole to be immortal. A system equally perfect in the marvellous forces within the minutest atom, the complex structure of organic molecular groupings, the infinity of cosmic dimensions, and the eternity of cosmic duration. There is no flaw in the vast design. Atoms clash, combine, and form molecules; and these break up again. Organisms are born and die. Worlds, systems, universes are evolved, play their part, disintegrate and disperse; only to reappear in new and complex relationships. The mighty cosmos remains ever rhythmic in its glorious energies.

Man's mind reels on the brink of the unfathomable when he tries to grasp the mystery even of himself. Everything impresses him with a feeling of profound humility in his own insignificance. At the same time, his surroundings force upon him the most absolute faith in the perfection of the great whole of which he is so minute a part. In contemplating this perfection one feels certain that the present disorder and misery of the world are merely that brief paroxysm of apparent chaos from which order will issue. Is it credible that the evolution of mental power—which enables man to appreciate the superb grandeur of the infinite, which enables him to harness the forces of nature to serve his needs—shall suddenly cease? Is it credible that he will remain content to see supine indifference and selfishness destroy all that is lovely in life? Such ideas are incredible. One glimpse of the eternal assures us that the tangled affairs of human life will yet be fully unravelled.

May it not be that, just as the burnt child dreads the fire, so the awful effect of the selfishness which has produced the present misery amongst mankind may burn its lesson so deeply as to be ineffaceable in human history? Nordau has pointed out that pleasurable emotion alone can be persistent, and that pain and misery are indications of decadence. If this be so, what a marvellous gospel of hope is contained in the religion of science! And should the theory of Partial Impact—this so-called unpractical theory of cosmogony—should it so awaken intelligence that the perfection of evolutionary methods may be learned, and the lesson acted upon in daily affairs, then such unpractical theories will prove richer than commerce or business or any of the material achievements so lauded by practical men. When the absolute beauty of the cosmos is realised by mankind, pain and misery will be suffered only till the alterations that are necessary for their removal can be ascertained; joy will be recognised more and more fully throughout the rolling æons whose infancy we dwell in — joy will be known as the true, the inalienable birthright of humanity.

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